This is a digital copy of a book that was preserved for generations on library shelves before it was carefully scanned by Google as part of a project to make the world's books discoverable online.

It has survived long enough for the copyright to expire and the book to enter the public domain. A public domain book is one that was never subject to copyright or whose legal copyright term has expired. Whether a book is in the public domain may vary country to country. Public domain books are our gateways to the past, representing a wealth of history, culture and knowledge that's often difficult to discover.

Marks, notations and other marginalia present in the original volume will appear in this file - a reminder of this book's long journey from the publisher to a library and finally to you.

Usage guidelines

Google is proud to partner with libraries to digitize public domain materials and make them widely accessible. Public domain books belong to the public and we are merely their custodians. Nevertheless, this work is expensive, so in order to keep providing this resource, we have taken steps to prevent abuse by commercial parties, including placing technical restrictions on automated querying.

We also ask that you:

+ *Make non-commercial use of the files* We designed Google Book Search for use by individuals, and we request that you use these files for personal, non-commercial purposes.

+ *Refrain from automated querying* Do not send automated queries of any sort to Google's system: If you are conducting research on machine translation, optical character recognition or other areas where access to a large amount of text is helpful, please contact us. We encourage the use of public domain materials for these purposes and may be able to help.

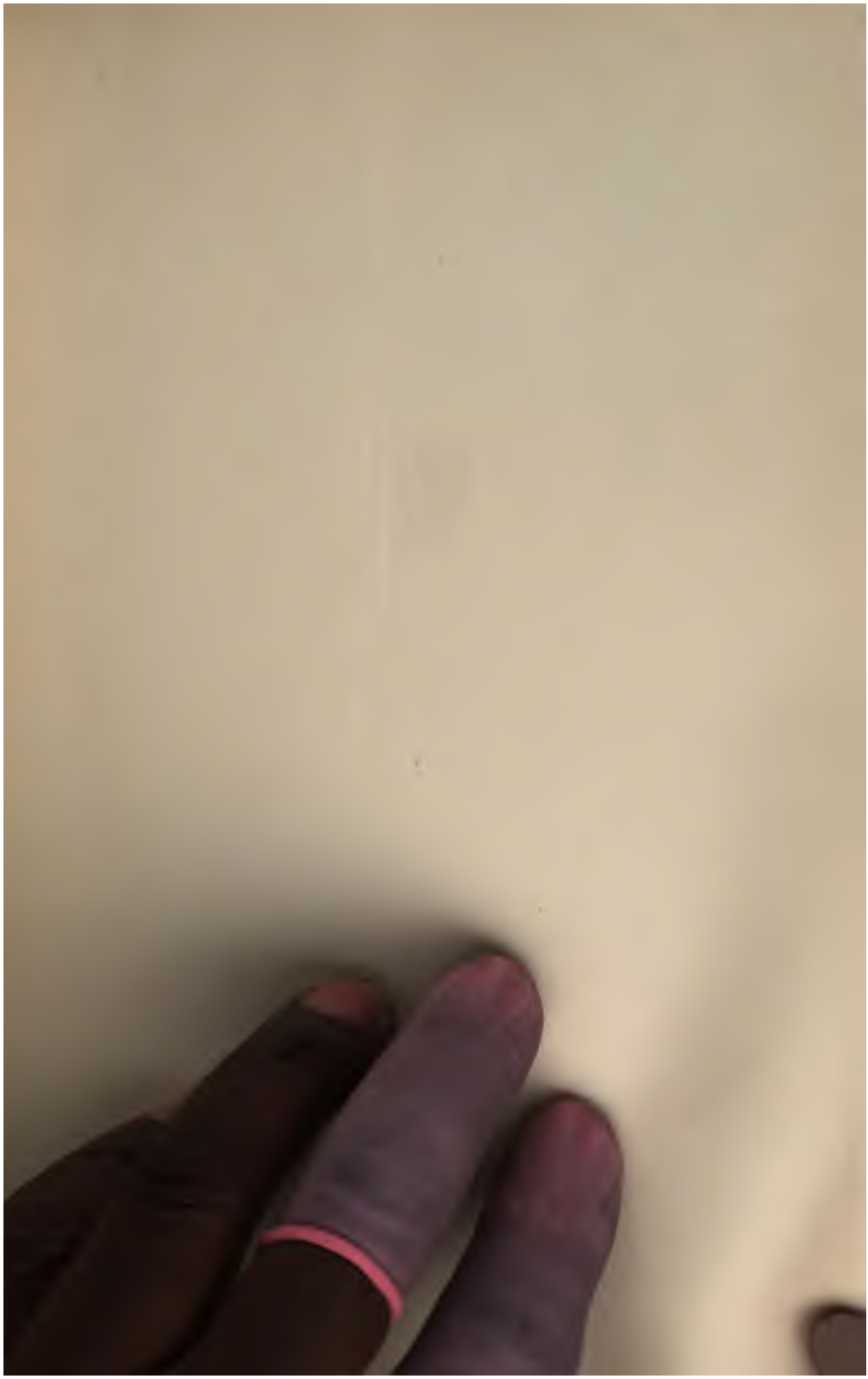
+ *Maintain attribution* The Google "watermark" you see on each file is essential for informing people about this project and helping them find additional materials through Google Book Search. Please do not remove it.

+ *Keep it legal* Whatever your use, remember that you are responsible for ensuring that what you are doing is legal. Do not assume that just because we believe a book is in the public domain for users in the United States, that the work is also in the public domain for users in other countries. Whether a book is still in copyright varies from country to country, and we can't offer guidance on whether any specific use of any specific book is allowed. Please do not assume that a book's appearance in Google Book Search means it can be used in any manner anywhere in the world. Copyright infringement liability can be quite severe.

About Google Book Search

Google's mission is to organize the world's information and to make it universally accessible and useful. Google Book Search helps readers discover the world's books while helping authors and publishers reach new audiences. You can search through the full text of this book on the web at `http://books.google.com/`

3 3433 06636833 7



POWER HOUSE OF THE UNION TERMINAL, WASHINGTON, D. C.
View showing 99 pivoted sash, in three separate lines each 200 *feet* long operated from one station

Radford's Cyclopedia of Construction

Carpentry, Building *and* Architecture

A General Reference Work on

MODERN BUILDING MATERIALS AND METHODS AND THEIR PRACTICAL APPLICATION TO ALL FORMS OF CONSTRUCTION IN WOOD, STONE, BRICK, STEEL, AND CONCRETE; INCLUDING ALSO SUCH ALLIED BRANCHES OF THE STRUCTURAL FIELD AS HEATING AND VENTILATING, PLUMBING, ELECTRIC WIRING, PAINTING, CONTRACTS, SPECIFICATIONS, ESTIMATING, STRUCTURAL DRAFTING, ETC.

Based on the Practical Experience of a
LARGE STAFF OF EXPERTS IN ACTUAL CONSTRUCTION WORK

Illustrated

TWELVE VOLUMES

THE RADFORD ARCHITECTURAL COMPANY
CHICAGO, ILL.

COPYRIGHT, 1909
BY
THE RADFORD ARCHITECTURAL COMPANY

Radford's Cyclopedia of Construction

Prepared under the Supervision of

WILLIAM A. RADFORD

Editor-in-Chief

President of the Radford Architectural Company, Chicago, Ill
Editor-in-Chief of the "American Carpenter and Builder" and the "Cement World"

ALFRED SIDNEY JOHNSON, A. M., PH. D.

Editor in Charge

Author of "The Materials and Manufacture of Concrete," etc.
Formerly Editor of "Current History." Associate Editor of Numerous Standard Works of Reference

Partial List of Authors and Collaborators

JOHN P. BROOKS, M. S.

Associate Professor of Civil Engineering, and Acting Head of Department of Civil Engineering, University of Illinois

FRANK O. DUFOUR, C. E.

Assistant Professor of Structural Engineering, University of Illinois
Author of "Bridge Engineering," "Roof Trusses," etc.

DAVID P. MORETON, B. S.

Associate Professor of Electrical Engineering, Armour Institute of Technology

ALFRED G. KING

Consulting Engineer on Heating and Ventilating
Author of "Practical Steam and Hot-Water Heating and Ventilation," "Steam and Hot-Water Heating Charts," "Practical Heating Illustrated," etc.

ERVIN KENISON, S. B.

Assistant Professor of Mechanical Drawing and Descriptive Geometry, Massachusetts Institute of Technology
Author of a Practical Textbook of Mechanical Drawing

AUTHORS AND COLLABORATORS—(Continued)

LORING H. PROVINE, B. S.

Instructor in Architectural Engineering, Department of Architecture, University of Illinois

THOMAS TAIT, C. E.

Consulting Heating, Ventilating, and Sanitary Engineer
Member American Society of Inspectors of Plumbing and Sanitary Engineers
Member American Society of Heating and Ventilating Engineers

RICHARD T. DANA

Consulting Engineer
Chief Engineer, Construction Service Company, New York, N. Y.
Joint Author with Halbert P. Gillette of "Cost-Analysis Engineering"
Member American Society of Civil Engineers
Member American Institute of Mechanical Engineers

WILLIAM A. RADFORD

President, The Radford Architectural Company, Chicago, Ill.
Editor-in-Chief, "American Carpenter and Builder" and "Cement World"
Author of "Practical Carpentry," "The Steel Square," etc.

GEORGE W. ASHBY

Architect
Vice-President, The Radford Architectural Company, Chicago, Ill.

CHARLES W. RADFORD

Treasurer, The Radford Architectural Company, Chicago, Ill.

CHARLES D. WARNER

Editor "Cement World" and "Dealers Record."

BERNARD L. JOHNSON, B. S.

Editor "American Carpenter and Builder" and "Woodworkers Review"
Formerly Mechanical Engineer, Fitz-Hugh Luther Locomotive & Car Company, Chicago, Ill.

E. L. HATFIELD

General Manager, Cement World Company, Chicago, Ill.

IRA S. GRIFFITH, A. B.

Supervisor of Manual Training, Oak Park, Ill.
Member Editorial Board, Western Drawing and Manual Training Association
Formerly Professor of Mathematics, Eureka College
Author of "Essentials of Woodworking"

AUTHORS AND COLLABORATORS—(Concluded)

CHARLES EDWARD PAUL, S. B.

Associate Professor of Mechanics, Armour Institute of Technology
Member American Society of Mechanical Engineers
Member American Society for Testing Materials

EDWIN O. GREIFENHAGEN, B. S., C. E.

Office Engineer, Bridge and Building Department, Chicago, Milwaukee & St. Paul Railway

ALFRED W. WOODS

Architect
Inventor of "Wood's Key to the Steel Square"
Joint Author of "The Steel Square and Its Uses"

WILLIAM REUTHER

Expert on Modern Building Methods

T. B. KIDNER

Director of Manual Training and Household Science, Department of Education, Province of New Brunswick
Fellow of the British Institute of Carpentry

P. W. RATHBUN, B. S.

Consulting Engineer
Member American Society of Heating and Ventilating Engineers

EDWARD HURST BROWN

Editor "Painters' Magazine"

CHARLES P. RAWSON

Chief Draftsman, The Radford Architectural Company, Chicago, Ill.

I. P. HICKS

Architect and Contractor

Bibliography of Construction

BEING A SELECTED LIST OF STANDARD WORKS COVERING VARIOUS PORTIONS OF THE GENERAL FIELD OF CONSTRUCTION

In addition to the vast store of up-to-date practical information never before published, the editors have embodied in the Cyclopedia of Construction the cream of the world's best literature in this field, giving in condensed form the substance of everything essential in the experience of the past to enable the worker of the present to meet every problem likely to be met with under the conditions of ordinary practice.

For the sake, however, of those who may be interested in pursuing further study along various special lines, we furnish a list of important works that have appeared covering different portions of the field.

In this connection, the editors wish to express their thanks to American manufacturers and dealers in the machinery and materials of construction, as well as to proprietors and patentees of various special mechanical devices and processes, for valuable data, illustrations and suggestions.

Authorities on Construction

MANSFIELD MERRIMAN, C. E., Ph. D.

Professor of Civil Engineering, Lehigh University
Author of "Mechanics of Materials;" "Retaining Walls and Masonry Dams;" "Elements of Sanitary Engineering;" "A Textbook on Roofs and Bridges," etc.

HALBERT P. GILLETTE

Late Chief Engineer, Washington State Railroad Commission
Author of "Handbook of Cost Data for Contractors and Engineers"

JOHN C. TRAUTWINE

Author of "The Civil Engineer's Pocketbook"

FREDERICK W. TAYLOR, M. E., and SANFORD E. THOMPSON, S. B., C. E.

Authors of "A Treatise on Concrete, Plain and Reinforced"

FREDERICK E. TURNEAURE, C. E., Dr. Eng.

Dean of College of Engineering, University of Wisconsin
Joint Author of "Principles of Reinforced Concrete Construction;" "Theory and Practice of Modern Framed Structures," etc.

EDWARD GODFREY

Structural Engineer for Robert W. Hunt & Co.
Author of "Structural Engineering" (Book I—"Tables;" Book II—"Concrete."

A. PRESCOTT FOLWELL

Editor, "Municipal Journal and Engineer"
Author of "Sewerage;" "Water-Supply Engineering," etc.

AUTHORITIES ON CONSTRUCTION

IRA O. BAKER, C. E.

Professor of Civil Engineering, University of Illinois
Author of "A Treatise on Masonry Construction;" "Roads and Pavements," etc.

FRANK E. KIDDER, C. E., Ph. D.

Author of "Architect's and Builder's Pocketbook;" "Building Construction and Superintendence," etc.

CHARLES EVAN FOWLER, C. E.

President, Pacific Northwestern Society of Engineers
Author of "Ordinary Foundations"

FRED T. HODGSON, ARCHITECT

Author of "Modern Carpentry;" "Builder and Contractor's Guide, etc.

HENRY R. TOWNE

Author of "Locks and Builders' Hardware"

HENRY N. OGDEN, C. E.

Assistant Professor of Civil Engineering, Cornell University
Author of "Sewer Construction"

CHARLES E. GREENE, A. M., C. E.

Late Professor of Civil Engineering, University of Michigan
Author of "Trusses and Arches," "Structural Mechanics," etc.

WILLIAM H. BIRKMIRE, C. E.

Author of "Planning and Construction of High Office Buildings;" "Architectural Iron and Steel, and Its Application in the Construction of Buildings;" "Compound Riveted Girders;" "Skeleton Construction in Buildings," etc.

FRANK W. SKINNER

Lecturer on Field Engineering, Cornell University
Author of "Types and Details of Bridge Construction"

JAMES J. LAWLER

Author of "Modern Plumbing, Steam and Hot-Water Heating"

WILLIAM H. BURR, C. E.

Professor of Civil Engineering, Columbia University, New York
Author of "Elasticity and Resistance of the Materials of Engineering;" Joint Author of "The Design and Construction of Metallic Bridges"

HOMER A. REID

Assistant Engineer, Bureau of Buildings, New York City
Author of "Concrete and Reinforced Concrete Construction"

J. B. JOHNSON, C. E.

Author of "Materials of Construction;" "Engineering Contracts and Specifications;" Joint Author of "Theory and Practice in the Designing of Modern Framed Structures"

AUTHORITIES ON CONSTRUCTION

W. R. WARE

Formerly Professor of Architecture, Columbia University, New York
Author of "Shades and Shadows;" "Modern Perspective," etc.

JOHN CASSAN WAIT, M. C. E., LL. B.

Formerly Assistant Professor of Engineering, Harvard University
Author of "Engineering and Architectural Jurisprudence;" "The Law of Contracts," etc.

T. M. CLARK

Author of "Building Superintendence;" "Architect, Builder, and Owner before the Law," etc.

CLARENCE A. MARTIN

Director of College of Architecture, Cornell University
Author of "Details of Building Construction"

CHARLES H. SNOW

Dean of School of Applied Science, New York University
Author of "The Principal Species of Wood, Their Characteristic Properties"

GAETANO LANZA, S. B., C. E.

Head of Department of Mechanical Engineering and Applied Mechanics, Massachusetts Institute of Technology
Author of "Applied Mechanics"

A. W. BUEL AND C. S. HILL

Authors of "Reinforced Concrete"

NEWTON HARRISON, E. E.

Author of "Electric Wiring, Diagrams and Switchboards"

EVERETT U. CROSBY and HENRY A. FISKE

Authors of "Handbook of Fire Protection for Improved Risk"

GEORGE E. THACKRAY, C. E.

Structural Engineer, Cambria Steel Co.
Author of "Handbook of Information Relating to Structural Steel"

ALPHA PIERCE JAMISON, M. E.

Assistant Professor of Mechanical Drawing, Purdue University
Author of "Elements of Mechanical Drawing;" "Advanced Mechanical Drawing," etc.

RUSSELL STURGIS

Author of "A Dictionary of Architecture and Building;" "How to Judge Architecture," etc.

A. D. F. HAMLIN, A. M.

Professor of the History of Architecture, Columbia University, New York
Author of "A Textbook of the History of Architecture"

ROLLA C. CARPENTER, M. S., C. E., M. M. E.

Professor of Experimental Engineering, Cornell University
Author of "Heating and Ventilating Buildings"

AUTHORITIES ON CONSTRUCTION

I. J. COSGROVE

Author of "Principles and Practice of Plumbing"

WILLIAM PAUL GERHARD, C. E.

Author of "A Guide to Sanitary House-Inspection;" "Sanitation of Public Buildings," etc.

FRANK O. DUFOUR, C. E.

Assistant Professor of Structural Engineering, University of Illinois
Author of "Bridge Engineering—Roof Trusses"

H. H. CAMPBELL

Author of "Manufacture and Properties of Structural Steel"

IRA S. GRIFFITH, A. B.

Supervisor of Manual Training, Oak Park, Ill.
Author of "Essentials of Woodworking."

WILLIAM J. BALDWIN

Author of "Steam Heating for Buildings"

CLIFFORD DYER HOLLEY, M. S., Ph. D., and E. F. LADD, B. S.

Authors of "Analysis of Mixed Paints, Color Pigments, and Varnishes"

JAMES H. MONCKTON

Author of "Stair-Building"

HARMON HOWARD RICE

Author of "Concrete-Block Manufacture: Processes and Machines"

H. G. RICHEY

Superintendent of Construction, U. S. Public Buildings
Author of "A Handbook for Superintendents of Construction, Architects, Builders, and Building Inspectors;" "The Building Mechanic's Ready Reference"

J. A. L. WADDELL, C. E., D. Sc., LL. D.

Author of "De Pontibus;" "Specifications and Contracts," etc.

R. M. STARBUCK

Author of "Modern Plumbing Illustrated"

SYDNEY F. WALKER, M. I. E. E.

Author of "Electric Lighting and Heating"

ERNEST McCULLOUGH, C. E.

Author of "The Business of Contracting;" "Reinforced Concrete," etc.

GEORGE D. ARMSTRONG

Author of "Cyclopedia of Painting"

ELECTROTYPE FILING CORRIDOR, THE RADFORD ARCHITECTURAL COMPANY, CHICAGO, ILL.

Preface

THE Building Industry, in its various branches, is more closely identified than any other with the marvelous engineering progress of the present day and the untold possibilities of the future. To put all classes of workers in familiar touch with modern methods of construction and the latest advances in this great field, and to bring to them in a form easily available for practical use the best fruits of the highest technical training and achievement, is the service which the CYCLOPEDIA OF CONSTRUCTION aims to render.

The work is pre-eminently a product of practical experience, designed for practical workers. It is based on the idea that even in the larger problems of engineering construction, it is not now necessary for the ordinary worker in concrete, or steel, or any other form of material, to attempt the impracticable task of exploring all the highways and byways where the trained engineer or technical expert finds himself at home. The theories have been worked out; the tests and calculations have been made; observations have been recorded in thousands of instances of actual construction; and the results thus accumulated form a vast treasure of labor-saving information which is now available in the shape of practical working rules, tables, instructions, etc., covering every phase of every construction problem likely to be met with in ordinary experience. This is perhaps most apparent in the sections on *Cement and Concrete Construction, Plain and Reinforced.* To this subject, on account of its supreme importance as a structural factor of the present day, three entire volumes are devoted, embodying the cream of all the valuable information which engineers have gathered up to date. Much of this practical information now presented in this Cyclopedia, has never before been published in any form. By its use,

anyone is enabled to take advantage of the vast labors of others, and to bring to bear on any problem confronting him the results of the widest experience and the highest skill.

The keynote of the Cyclopedia is found in the emphasis constantly laid on the *practical* as distinguished from the *theoretical* form of treatment, in its total avoidance of the complicated formulas of higher mathematics, and in its reduction of all technical subjects to terms of the simplest and clearest English. Throughout the pages devoted to Steel Construction, for example, the mathematics of the subject have been eliminated to such an extent that *the reader will not find a single instance where even a square root sign has been used.*

In addition to the larger problems of engineering and building construction, one entire volume, as well as many chapters scattered through the work, is devoted to those smaller constructions that are of special interest to the teacher or student of manual training or the home shop worker of a mechanical turn of mind.

Inasmuch as a wider knowledge and a more intelligent grasp of the fundamental principles of construction and design will tend to greater efficiency on the part of workingmen, and to greater economy in production, the purpose of the CYCLOPEDIA OF CONSTRUCTION is one which will appeal strongly, not only to the men themselves, but also to the architectural and engineering fraternity as a whole.

The authors of the various sections are all men of wide experience whose recognized standing is a guarantee of reliability and practical thoroughness.

Table of Contents

MODERN HEATING SYSTEMS . . . . . PAGE 1

Historical Sketch—Hot-Air Heating—Size and Location of Furnace—Registers and Flues—Safety Piping—Heat Pipes—Cold-Air Supply—Air-Cleansing—Furnace Ventilation—Steam Heating—Water-Hammer—Eccentric Fittings—How to Determine Radiation—Selection of Boiler—One-Pipe Circuit System—Divided-Circuit System—Dry Returns—Wet Returns—Sizes of Main and Return Pipes—Overhead System, Steam—Two-Pipe System for Steam—Radiator Connections—Hot-Water Heating—Gravity and Forced Circulation—Two-Pipe System, Hot Water—Expansion Tank—Distributing Fittings—Overhead System, Hot-Water—Circuit or Single-Main System, Hot Water—Fittings for Improving Circulation (Eureka, Phelps, etc.)—Pressure Systems—Accelerated Systems—Piping and Radiator Tappings—Hydro-Vacuum Circulator—Milwaukee Heat-Generator—Direct, Direct-Indirect, and Indirect Radiators—Sizes of Ducts and Registers—Stacks—Coils—Valves (Globe, Angle, Gate)—Radiator Valves—Check-Valves—Air-Valves—Boiler Trimmings—Water Column and Gauge—Gauge-Cocks—Steam Gauge—Automatic Damper-Regulators—Safety-Valves—Thermometers—Altitude Gauge—Chimney Flue Construction—Vacuum and Vapor Heating—Vacuum Systems (Webster, Paul, Van Auken, Trane, etc.)

VENTILATION AND TEMPERATURE REGULATION PAGE 142

Importance of Ventilation—How Air is Contaminated—Humidity—How Ventilation is Secured—Fans, Blowers, Air-Washers, etc.—Location of Ventilating Registers—Forced Circulation of Air—Automatic Temperature Regulation—Thermostat—Electric and Non-Electric Automatic Regulators—Pipe and Boiler Insulation—Asbestos Paper.

PLUMBING . . . . . PAGE 161

Sewer and Connections—Traps and Ventilation—Rain-Water Pipes—Sizes of Drains and Sewers—Cistern Overflows—Fresh-Air Inlet—Roughing In—Cutting Soil-Pipe—Soil-Pipe Joints—Piping System (Drain, Soil, Waste, Vent, and Water Service)—Laundry Tubs—Floor Drain—Sink—Range Boiler—Gas Heater—Lavatories—Bathtub—Closets—Vertical Pipe Work—Waste and Vent Pipes—Connecting Fittings—Reducing Coupling—Increaser—Roof Flashing—Continuous Venting—Sanitary Tees—Drum Traps—Water Service Pipes—Stop and Waste Cocks—Compression Tank—Refrigerator Wastes—Testing Plumbing (Water, Smoke, Peppermint)—Hot-Water Supply—Boiler and Water-Back Connections—Tank Heater—Instantaneous Hot-Water Heaters—Electric Water-Heater—Automatic Water-Heaters—Useful Tables, Rules, Recipes (Sizes, Capacities, Weights, etc., of Fixtures, Friction Losses, Recipes for Cements, Cleaning, etc.)—Municipal Regulations—Plumbing in Office Buildings—Sewage Ejectors—Drainage Fittings—Range Closets—Siphon-Jet Closets and Urinals—Flush-Valves—Factory Plumbing—Model Toilet-Room—Private Pneumatic Water Systems—Waterworks for Small Town—Marine Plumbing—Private Sewerage Systems—Cesspools—Sewage Disposal—Farming Process—City Sewage Disposal—Septic Tank and its Operation—Lift and Force Pumps—Hydraulic Rams—Hot-Water Tank Regulator—Automatic Water-Heaters—Air-Lift.

INDEX . . . . . PAGE 321

PART VIEW OF VENTILATING SYSTEM OF THE WALDORF-ASTORIA HOTEL, FIFTH AVENUE AND BROADWAY, NEW YORK CITY.

Photograph showing 60-inch ventilators after 12 years of service.

Heating and Ventilation

The health and comfort—and, we might also say, the peace of mind—of the inmates of a building, depend to a very large extent on the adoption of a proper system for heating and ventilating the structure. This is true of the small house as well as of the large, of the sky-scraper as well as the bungalow, and of the concrete house as well as that built of stone or brick or wood or other structural material. An efficient and economical installation for warming the structure equably, and at the same time keeping it constantly furnished with an adequate supply of fresh air—for these two functions are very closely related—is a matter of vital importance. Every home-builder and home-owner, everyone engaged in or interested in building construction, should understand at least the elementary principles involved in the selection and mechanical installation of a good heating and ventilating system.

Historical Sketch. Probably no part of the construction of the modern residence or business building has been subjected to more changes and improvements—particularly dur-

ing the last decade—than have the methods involved in its heating and ventilation.

From the time of the braziers of the ancient Romans, in which carefully dried wood was burned, to the date of the old Franklin stove (1844), a period of many centuries, improvements in heating methods were few, consisting mainly in the installation of various types of open fireplaces. The first attempts at chimney building of which we have record, appear to have been made by the Venetians in 1344, and the open fireplace doubtless followed soon after.

With the discovery and use of coal as fuel, came the necessity for the provision of some form of appliance in which this material could be burned properly; and the period immediately following might accordingly be designated as the "era of stoves." This period was succeeded by the advent of the early type of warm-air furnace—another improvement which was the direct result of necessity. As towns and cities sprang up and developed in accordance with the natural growth of the country, property values advanced and buildings of increasing proportions were erected. The problem necessarily arose, of how to give proper attention to the large number of stoves required for heating these larger buildings. The attempt to solve this problem led to the adoption of an appliance which afforded a centralizing of the fire in one place; and the first furnace—merely a large bricked-in stove—was the result.

The latter half of the nineteenth century witnessed the general adoption of steam and hot-water apparatus as a medium for conveying heat to all parts of a building; and along this line improvement followed improvement so rapidly that, with the beginning of the twentieth century, we were able to heat any structure to any stated degree of temperature regardless of weather conditions, and at the same time were able to change the air within the same building as many times per hour as necessity required. In other words, the principles in the heating and ventilating of buildings had been reduced to an exact science, and their practical application in the installation of such systems to an art.

In the following pages we shall treat of modern heating and ventilating apparatus, aiming to acquaint our readers with up-to-date methods in vogue for providing a proper and sufficient supply of heat and fresh air to our homes.

Modern Heating Apparatus

Modern heating apparatus may be divided into three principal classes: (1) **Hot-Air;** (2) **Steam;** (3) **Hot-Water,** with several adaptations of the two latter divisions. To these may rightly be added the later types of apparatus belonging to systems of heating known as the "vapor," "vacuum," and "vacuo-vapor" systems, and the several accelerated systems of hot-water heating.

Time was, and that not so long ago, when the builder gave little or no attention to the proper heating of a structure until every other part of it had been provided for. Now, however, the question "How shall I heat the building?" or "What type of apparatus shall I use?" is considered along with those relating to the other features that enter into the construction of the building, and the heating plant is arranged for as soon as the building plans are matured.

Of the three principal modern methods, hot air is the easiest and cheapest to install. Next in order is the steam-heating apparatus, with the hot-water heating system following last; and the degree of general efficiency derived from the three—considering results obtained, cost of fuel required, and length of service with freedom from repairs—can be truly regarded as being also in the order named.

The average life of a hot-air furnace is from eight to twelve years; of a steam heating apparatus (cast-iron boiler), from twenty to twenty-five years; and of a hot-water heating apparatus (cast-iron heater), thirty years or more. During the periods named, the hot-air furnace is most efficient the first four or five years, after which limit it deteriorates rapidly in the efficiency of the service rendered, invariably requiring considerably more fuel and giving proportionately less satisfactory results. The efficiency of service produced by the steam or the hot-water apparatus does not alter with time; and, when kept clean and in condition, these types of heating plant do not require an additional amount of fuel from year to year.

A question quite frequently asked is: What difference, if any, is there in the fuel consumption of either system? Assuming that a certain building will require fifteen tons of anthracite coal to heat it with hot air, it has been proven that the same results may be obtained with a steam heating apparatus from twelve tons of fuel, or with a hot-water heating apparatus from ten tons of fuel—a saving, in the latter instance, of one-third of the amount of fuel required by the hot-air furnace to accomplish the same service.

It should be borne in mind that the character of the installation of either system of heating has much to do with its efficiency and its economical operation, and the comparisons

above given are computed on the basis that each type of apparatus is properly installed.

Hot-air furnaces can be installed in buildings which are not severely exposed to prevailing winds, and will give a sufficient quantity of heat to insure satisfactory service. There is no building, however, regardless of the extent of its exposure, which cannot be satisfactorily heated with either steam or hot water. And yet, if too small an amount of radiation be provided, or if the radiation, though of sufficient quantity, be improperly placed, or if too small a boiler be installed, or a poor system of piping be erected, these conditions will render the steam or hot-water apparatus inefficient and unsatisfactory.

In providing for the installation of a modern heating apparatus, there are some features of building construction which should have the careful attention of the builder. The colder the climate, the greater the necessity for constructing the building in such a manner as will enable it effectively to resist the cold weather. The small additional sum required to make all parts of the structure tight, sound, and capable of resisting and excluding the cold, is, in a comparatively short time, more than refunded in the saving on fuel bills, to say nothing of the satisfaction of having a warm and comfortable home at all times, regardless of varying climatic conditions.

Air is a good insulator; and in building out-

side walls, provision should be made for "dead" air spaces. If of frame construction, the outer wall should be lathed and plastered tightly on the inside. The studding should be sheathed outside and the sheathing carefully covered with a good quality of building paper. A poor grade of paper is useless at any price. This surface should then be tightly and securely covered with shingles, matched siding, or clapboards. In a particularly cold climate, it is well to sheath the inside of the studding and "furr out" before lathing and plastering. Brick walls should in every instance be "furred out" on the inside; and in cold climates the use of double windows and storm doors is particularly advisable.

The efficiency and the economical operation of the heating apparatus will depend largely on the accuracy with which the above suggestions have been carried out.

HOT-AIR HEATING

The "hit or miss" methods which have been and are still followed to a great extent in the installation of furnaces and other details of hot-air heating apparatus, have brought this type of modern heating system into general disrepute by reason of the poor results necessarily obtained. In many cases the furnace-man or tinner seems to possess no idea of the proper method to follow in setting the furnace, running the hot-air pipes, or locating the registers; or—if knowing—seems not to care. It is careful

attention to these details, however, which will naturally assist in securing a satisfactory job.

Cheap competition work incidental to large building operations where several houses or groups of houses are erected collectively in rows or in pairs and offered for sale by the builders—"operation work," as it is called—has resulted in the placing of thousands of furnaces too small in capacity to operate properly, and of so cheap a construction as to be practically worthless after a few seasons' use.

The proper preparation of a building for the installation of a furnace begins with the foundation, as the chimney for the use of the apparatus should be located in such a position that the furnace may be set well towards the north and west sides of the cellar or basement. The furnace should be placed in this position in order to have the shorter warm-air pipes serve the colder part of the house, as it is extremely difficult to force warm air towards the north or west through piping of exceptional length.

Under ordinary conditions the furnace should be set not more than six feet distant from the chimney flue. It is far better, however, to double the length of the smoke pipe in order to be able to locate the furnace toward the west or north, than it is to double the length of the hot-air pipes, if either one of these two contingencies arises.

To illustrate the proper method of installing a hot-air furnace, we shall consider its applica-

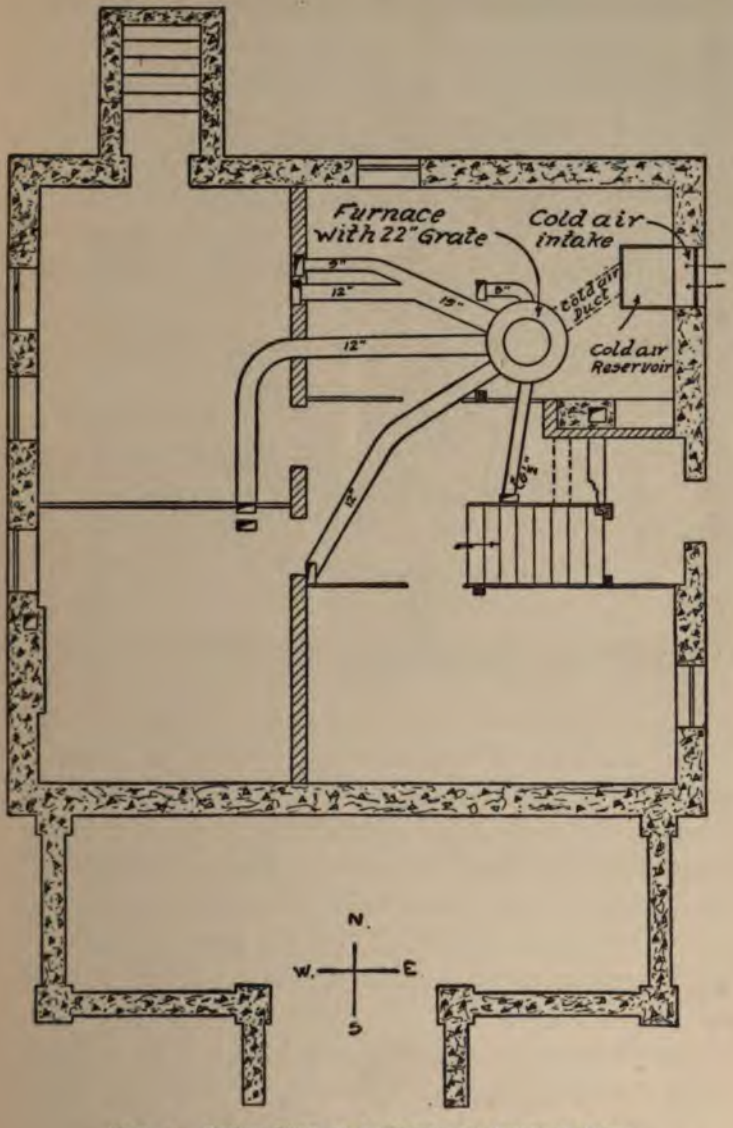


Fig. 1. Cellar Plan of a House of Average Size.

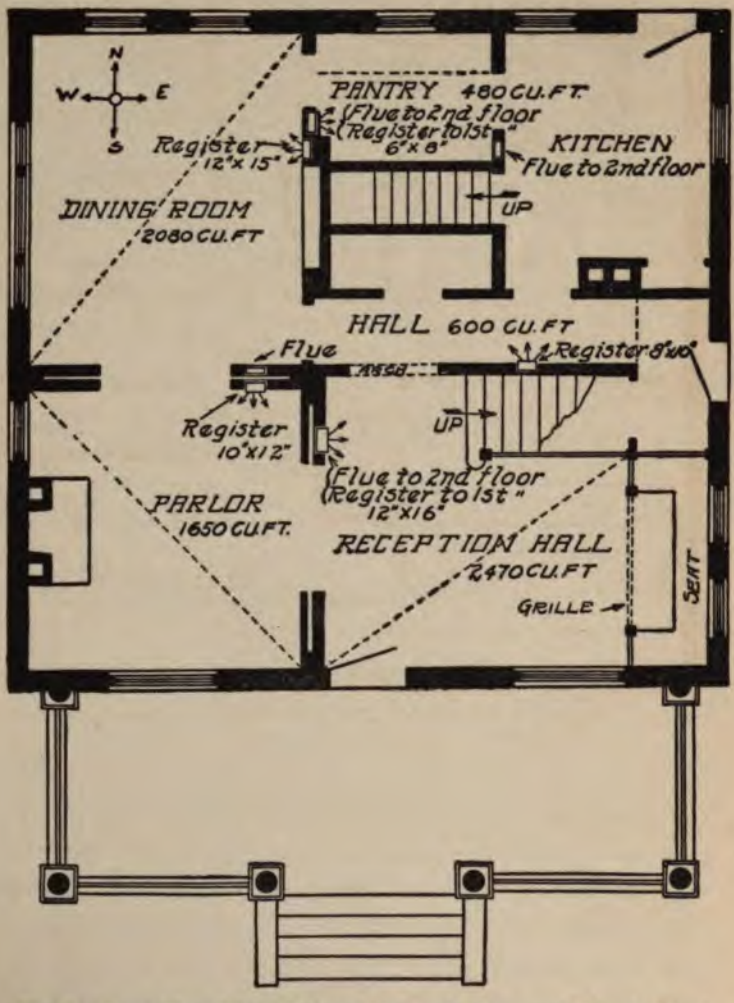


Fig. 2. First-Floor Plan of House Shown in Basement Plan in Fig. 1.

tion to a house of average size. Fig. 1 shows the cellar plan, Fig. 2 the first floor, and Fig. 3 the second floor plan of such a house.

Size of Furnace Required. Having deter-

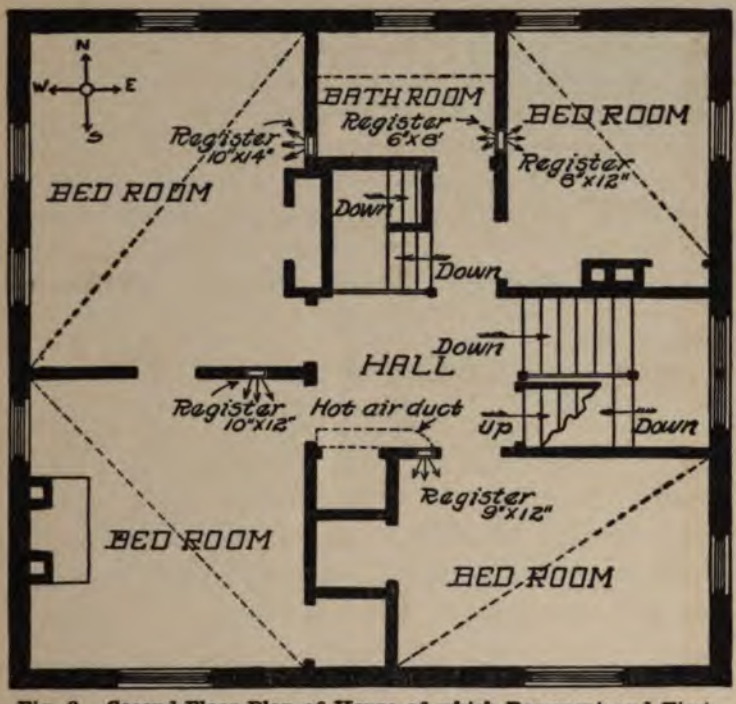


Fig. 3. Second-Floor Plan of House of which Basement and First-Floor Plans are Shown in Figs. 1 and 2.

mined upon the installation of a furnace, the first thing to consider is the size necessary. For arriving at this conclusion, there are several methods that can be adopted. We shall assume that it is desired to have an apparatus of sufficient capacity to heat all rooms (excepting the kitchen) to 70° F. in zero weather. An excellent rule, formulated by Mr. Charles S. Prizer, is as follows:

"Find the cubic feet of space in room by multiplying the length by the width, and this product by the height. To the actual cubic feet of space in the room, add 75

cubic feet for each square foot of glass surface (outside doors to be figured as glass), and 8 cubic feet for each square foot of outside or exposed wall surface. For either a northern or western exposure, add 10 per cent to the glass surface and 10 per cent to the wall surface. For either a southern or eastern exposure, deduct 10 per cent from the exposed glass and wall surface. Should double doors or storm doors be used, count outside doors as exposed wall instead of exposed glass surface. Add together the figures for all rooms to be heated, and the total will be the **equivalent cubic feet** of space to be provided for by the furnace."

This rule, it will be observed, takes into account the various exposures of each and every room. In the event of the house being located in a section where a temperature of 10° to 12° above zero is the extreme degree of cold weather, 10 per cent may be deducted from the "equivalent cubic feet." For locations where the extreme degree of cold weather is 10° below zero, add 10 per cent to the equivalent cubic feet; for 20° below zero, add 15 per cent; and for 30° below zero, add 20 per cent.

Select a furnace having one square inch of grate area for each 150 equivalent cubic feet of space to be heated.

A simpler rule, quite accurate in the results obtained, is to allow one square inch of grate area in the furnace for each 40 actual cubic feet of contents, if the house to be heated is well constructed and is exposed on all sides. If part of a double structure, or one of a row of houses, use the number 50 as the divisor.

The house illustrated in Figs. 1, 2, and 3 has slightly more than 15,000 actual cubic feet to be warmed, and is an isolated structure. Therefore, 15,000÷40=375 square inches of grate surface required. This would call for a grate approximately 22 inches in diameter (a

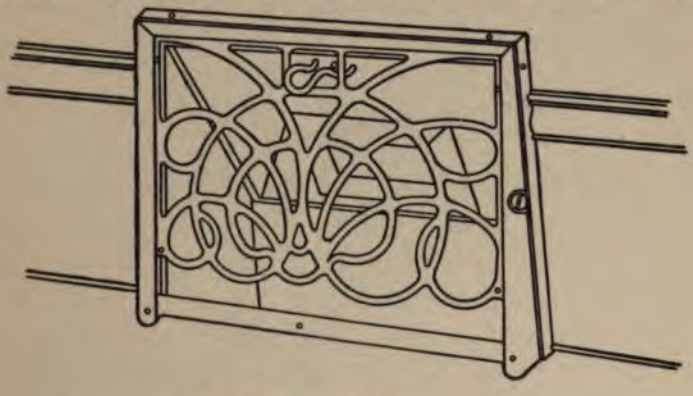


Fig. 4. Side-Wall Register.

circle 22 inches in diameter gives an area of 380.13 sq. in., or slightly more than necessary).

Location and Size of Registers and Flues. Registers should be located along or in the inner walls of each room. The dotted lines dividing the floor space of the various rooms in Figs. 2 and 3, explain this. The registers should be placed **inside** the dotted lines. Formerly it was considered good practice to use floor registers for all first-floor rooms, and wall registers for the rooms above the first floor. However, the recent introduction of the improved side-wall register, Fig. 4, has changed this former idea. By the use of this type of register in a three-

or four-inch wall, an opening for a flue at least 7 inches deep is obtained by cutting out 2 inches of the floor. This, together with the space of 1 inch occupied by lath and plaster, gives a flue 3 inches deeper than the studding, and allows

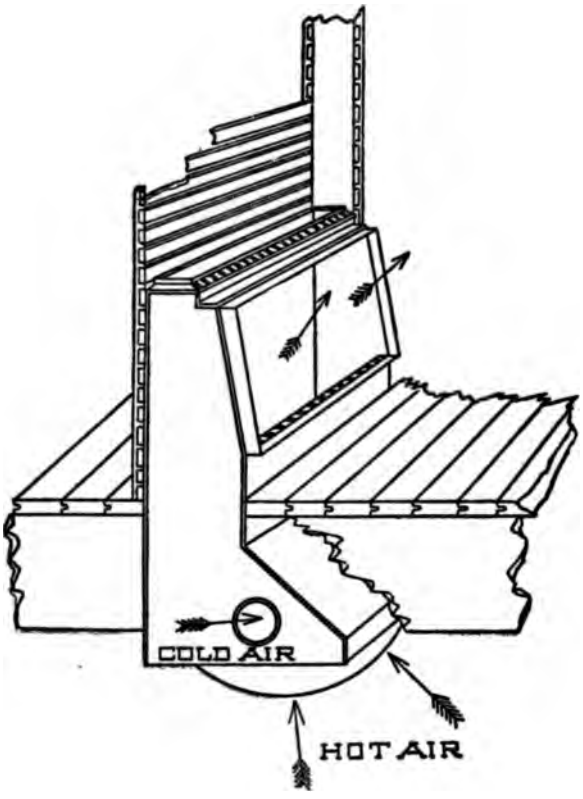


Fig. 5. Wall Prepared for Side-Wall Register.

the placing of an effective register for warming first-floor rooms. In a similar manner a single flue can also be made to heat a first and a second floor room, thus simplifying the piping system

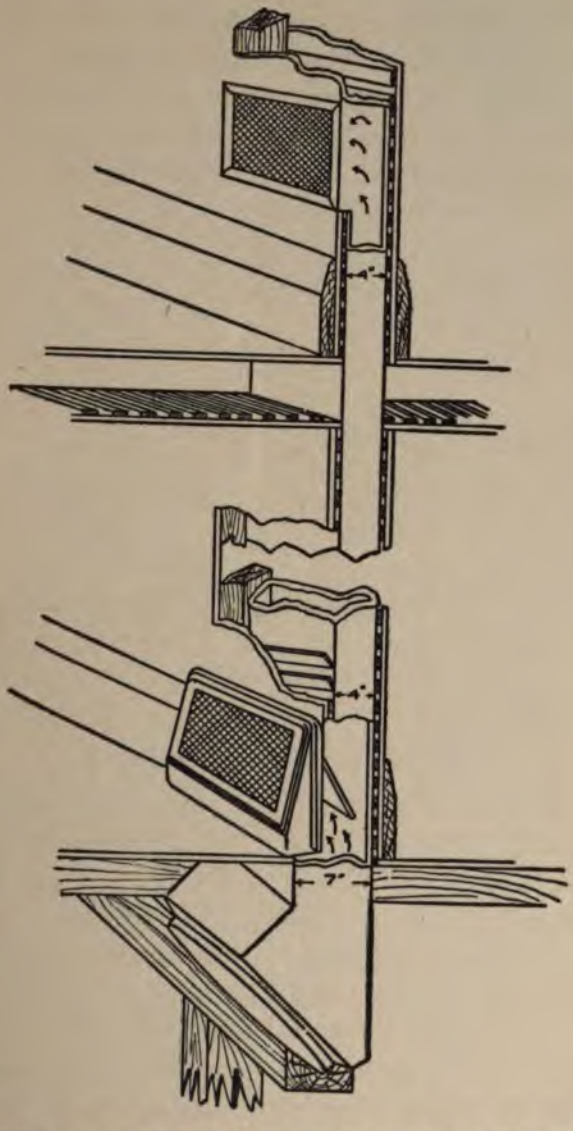


Fig. 6. Stack Supplying First- and Second-Floor Registers.

and lessening the number of pipes in the cellar.

There is much to be said derogatory to the use of the floor register. It is a dust and dirt collector; it frequently interferes with the desired placing of furniture and often necessitates the cutting of carpets. All these adverse

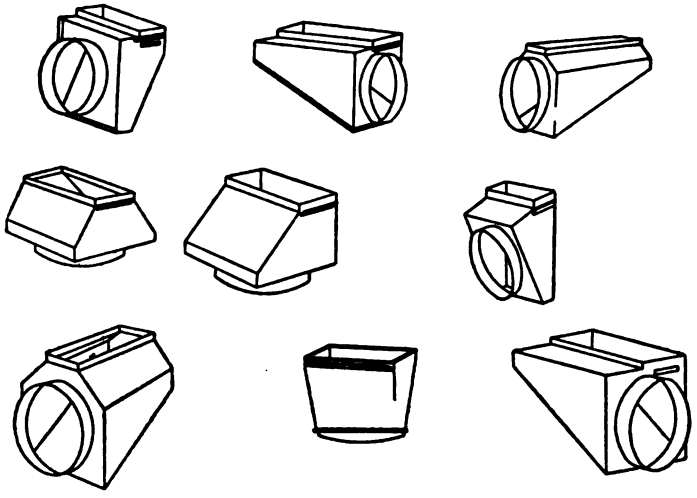


Fig. 7. Correct Forms of "Boots."

conditions are obviated by using the side-wall register. Fig. 5 shows the wall prepared and the opening cased ready for the insertion of the cast-iron register frame. Fig. 6 shows a stack supplying the first and second floor registers. Note that by this arrangement, as cited above, the depth of the flue supplying the first floor is 7 inches. A baffle-plate divides the flow of warm air, furnishing each floor with its proper proportion of heat.

The fitting at the bottom of a stack, or verti-

A TYPICAL EXAMPLE OF MODERN MILL-BUILDING CONSTRUCTION.

Shops of a large machine company at Springfield, Vt. Note the splendid provision for lighting; also the saw-tooth roof construction and complete equipment of 20-inch metal top ventilators.

cal duct, supplying a register, is termed a **boot.** The round pipe in basement conveying hot air from the furnace is connected to a boot, which must be so arranged as to receive the full volume of this round pipe and distribute it to the riser with the least possible amount of friction.

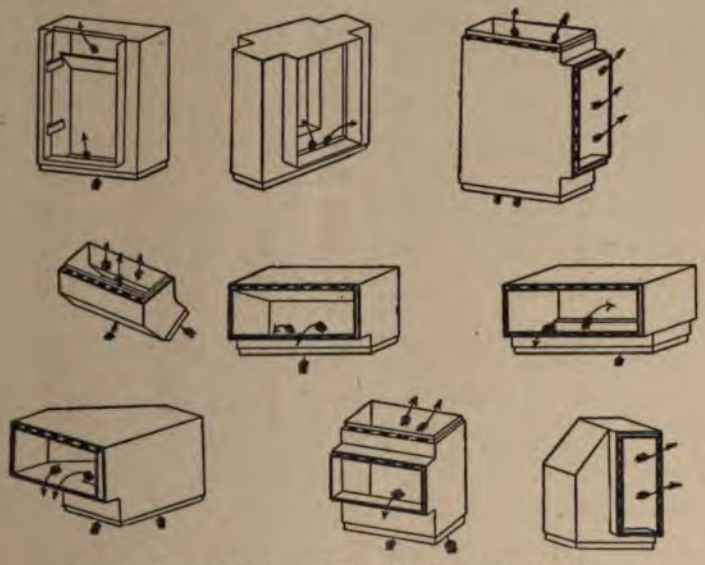


Fig. 8. Correct Forms of Flue-Heads or Register Boxes.

A variety of designs are therefore necessary to answer suitably certain requirements, and Fig. 7 shows a number of correct forms.

The fitting at the top of a riser or flue is termed a **flue-head** or **register box.** These are made in a form to supply a single register, or they may be so arranged as to be suitable for supplying registers on opposite sides of the

partition. Fig. 8 illustrates some correct forms of this fitting.

In the running of all furnace piping, abrupt bends and acute angles should be avoided, so that the heat-carrying pipes may offer the least possible amount of friction or resistance to the flow of warm air through them.

All hot-air pipes should be covered with asbestos paper, or, better, with asbestos air-cell covering. Should circumstances require the placing of a pipe within an outside wall, its outer surface should be doubly covered in a permanent manner with first-class material. Asbestos air-cell covering also affords a protection against fire liable to be caused by an overheated pipe.

In this connection it is advisable to call attention to a new type of furnace piping, as illustrated in Fig. 9. The design is called **Safety Pipe,** and is of double construction with an air space between the two layers of metal. A small opening through the outer pipe in the boot admits cellar air.

Table I will give the measurements of registers necessary for supplying certain sizes of rooms, the sizes of flues (vertical pipes), and the sizes of the round pipe in the basement conveying warm air from the furnace to the boot. In all cases where two or more rooms are heated from one pipe, this pipe must have sufficient capacity to carry the required amount of warm

air for all rooms served by it, according to the information given in the table.

Heat Pipes. The heat pipes conveying air from the furnace should have a good upward slope in the cellar. If necessary, the bottom of the furnace should be placed below the level of the cellar floor, in order to secure a slope in the heat pipes. When it is necessary to use pipes of different lengths to reach different rooms of the same size, the longer pipes should be larger in diameter than the shorter pipes. When a large number of heat pipes are taken off from the furnace, they should average smaller in diameter than the average diameter when there are but a few heat pipes.

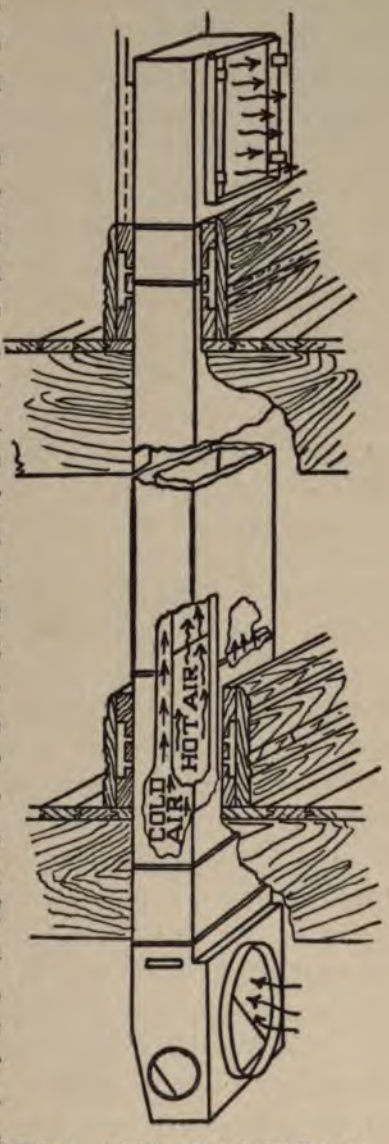


Fig. 9. Double "Safety" Piping.

TABLE I

Sizes for Furnace Pipes and Registers

Size of Room (Cubic Feet of Space)	Size of Room (Floor Space if 10 Ft. Ceiling)	Size of Round Pipe in Cellar	Size of Register and Register Boxes	Area of Open Space in Register (Bars Removed)
500	6 x 8 ft.	7 in.	6 x 8 in	85 sq. in.
850	8 x 10 "	8 "	8 x 10 "	45 " "
1,000	9 x 11 "	8 "	8 x 12 "	55 " "
1,250	10 x 12½ "	9 "	9 x 12 "	60 " "
1,650	12 x 14 "	9 "	10 x 12 "	70 " "
2,000	12 x 17 "	10 "	10 x 14 "	80 " "
2,800	14 x 17 "	12 "	12 x 15 "	115 " "
2,600	15 x 18 "	12 "	12 x 17 "	120 " "
3,000	15 x 20 "	14 "	14 x 20 "	156 " "
4,000	20 x 20 "	16 "	16 x 24 "	210 " "
5,400	20 x 27 "	18 "	20 x 24 "	270 " "
7,000	20 x 35 "	20 "	21 x 29 "	340 " "

The total capacity of all the heat pipes leading from a furnace should never exceed 40 per cent of the area of the circle of the casing; and in good furnace practice, this total capacity of heat pipes should usually be considerably less than 40 per cent of the area of the circle of the casing.

In practice the diameters of the several pipes must be determined by the conditions and requirements of each particular case. The capacity of heat pipes leading to vertical partition flues for heating rooms in upper stories, may be somewhat less than that of pipes running to first-floor rooms. When the vertical flues are of sufficient capacity, it is seldom difficult to convey heat to second or third floor rooms, unless the mistake is made of attempting to carry the heat up in exposed outer walls.

When the cone-top upper casing is used, the several pipes should be brought out from the

sloping sides as high up as possible, and the top sides of the pipes should all be on an exact level. Where the straight-sided flat-top upper casing is used, the pipes are brought out from the top, in which case the elbows should all be of the same height from the top of the furnace. Both heat pipes and smoke pipe should be perfectly tight, so that no air can enter them except through the furnace.

Cold-Air Supply. No hot-air furnace will do its work properly unless provided with an adequate cold-air supply. In the cheap form of installation, it is invariably noted that the furnace is supplied with basement air through a fretwork base of the furnace. Aside from showing poor practice, this method creates an unhealthful condition. Air from outside the building itself should be used; and the necessary supply should, if possible, be admitted from the north or northwest sides. A cellar window may be utilized for the purpose. Just inside the cellar window or other similar suitable opening, the cold-air duct should be enlarged to about three times the required capacity. From the bottom of this duct the connection with the furnace may be made, the pipe running either below the floor of the cellar or above it, according to circumstances surrounding the installation. This large duct forms a reservoir for the accumulation of cold air, and this reserve supply prevents prevailing high or variable winds from interfering with the steady flow of air to the furnace.

Fig. 10 will illustrate this idea. The outside entrance to the opening should be protected with a coarse wire screen fastened in a permanent manner. We favor the building of a cold air

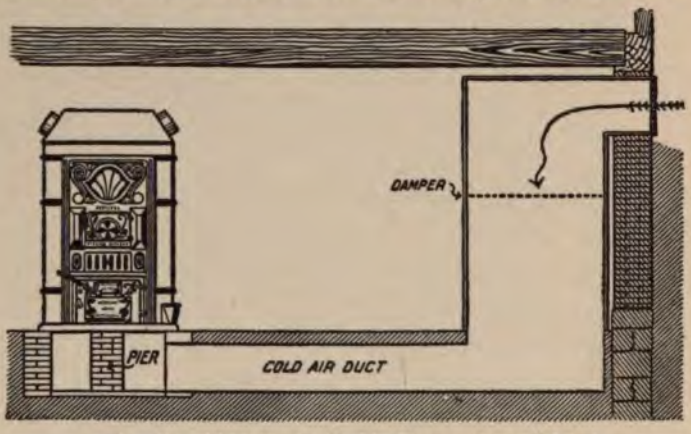


Fig. 10. Showing Cold-Air Reservoir and Duct.

pit of brick beneath the furnace, as illustrated in Fig. 11.

In size, the cold-air duct should have three-fourths of the area of all heat pipes leading from the top casing. For example, let us assume a job having:

One 8-inch heat pipe, capacity.....	50 sq. in.
Two 9-inch heat pipes, capacity.....	126 sq. in.
Three 10-inch heat pipes, capacity.	234 sq. in.
Total	410 sq. in.

Here the total area of the heat pipes is 410 square inches. Three-fourths of this total capacity is 307 square inches; therefore the

dimensions of the cold-air duct should be 12 × 25 inches = 300 square inches.

Cold-Air Cleansing. In some localities, such as factory districts, or in places where soft coal is extensively burned, it is desirable to cleanse the cold-air supply prior to its admission to the furnace. A simple method for accomplish-

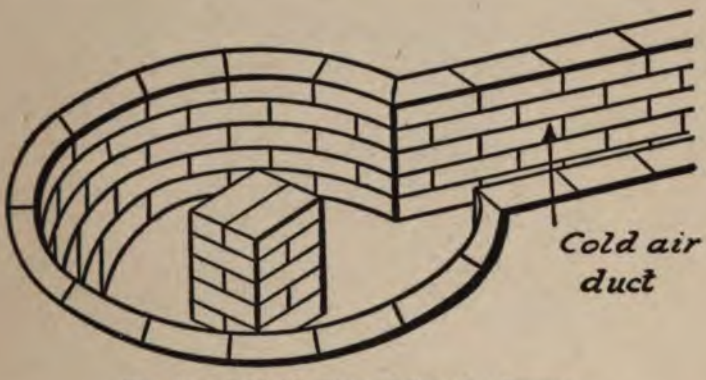


Fig. 11. Cold-Air Pit and Pier for Furnace.

ing this desired result is illustrated in Fig. 12. Frames partially covered with cheese-cloth are inserted in the cold-air chamber or reservoir. These frames are set at an angle of about 30 degrees, the clear openings through them being "staggered" or located on alternate sides of the chamber, as shown. They should be fitted in grooves, and so made as to be easily removable for the purpose of cleaning or re-covering. This simple arrangement will be found very efficient.

Furnace Ventilation. The air we breathe contains more or less carbonic oxide—a poisonous gas which, within a crowded room, is present

in the air to such an extent as to cause the occupants headache and other similar ailments. This contamination of the air is caused by the poisons given off in the exhalations or from

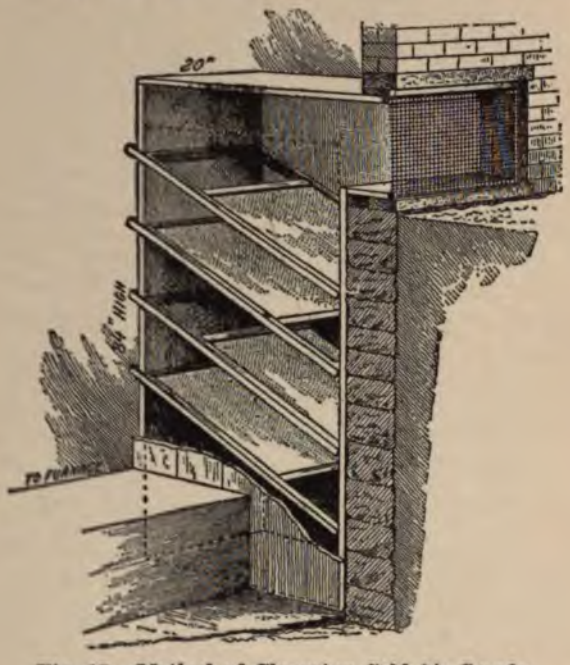


Fig. 12. Method of Cleansing Cold-Air Supply.

the bodies of the people within the room. Therefore, by reason of its effect upon the physical body, proper ventilation is of even greater importance than heating, and is consequently an essential and inseparable part of the heating problem. It therefore calls for at least some brief pertinent suggestions.

In winter, rooms should be ventilated by taking out air at or near the floor. Taking out

air from the top of the room for ventilation is wrong in principle, and always interferes with heating the room. An excellent plan to ventilate a residence is to build a large ventilating shaft instead of the usual chimney flue. Up through this shaft, run a tight terra-cotta or metal smoke pipe to carry the draft of the furnace. The space in the shaft around the smoke pipe is ventilating space, which will be warmed by the draft of the furnace, causing a strong upward current of air in the shaft. A pipe or duct of any form or shape or material that may be found most convenient should be run from the floor or baseboard of each room to this upright ventilating shaft. In this way the lower strata of air will be drawn off from the rooms, and a constant and reliable change of air will be assured. The ventilating register in each room should have about sixty per cent of the capacity of the heat register through which hot air is supplied for heating the room. This method of ventilation is comparatively inexpensive, if put in at the time the house is built.

Where there is no mechanical device for forcing ventilation, the main ventilating shaft must be warmed so that there will be maintained an upward current of air in it; a cold ventilating shaft is worse than none at all. It is easier to heat rooms that are properly ventilated than to heat them when there is no provision for systematic ventilation. In a properly ventilated house, the colder and impurer air is being con-

stantly drawn off from the lower parts of the rooms; the fresh warmed air is filling the rooms from the top downward, and this warm air is not working against resistance.

It is extremely difficult and requires an extravagant consumption of fuel to heat a church or hall with a very high ceiling, without drawing off the cold air from the lower part of the room. In such cases, where the dealer cannot induce the owner of the building to put in a ventilating shaft, satisfactory results may be attained by supplying the furnace with cold air drawn through a cold-air duct from the room above the furnace; but the usual provision should be made, when this plan is adopted, for supplying cold air from the outside. The duct from the outside and the one from the room above should be joined into one duct before reaching the furnace, so that, by placing a turn damper at the junction, the supply of cold air can be taken from outside, if desired, when the room above is well heated and when there are a number of people in it.

STEAM HEATING

Steam heating is unlike hot-air heating in principle, as well as in results attained. In heating a room with hot air, the register distributes the heated air to the room, this warm air ascending to the ceiling, and then descending to the floor as it becomes heavier after cooling. A steam radiator circulates or turns the air in

the room, as shown by Fig. 13. Note the downward circulation of the cold air from the window, as indicated by arrows.

Weather conditions do not affect the efficiency of steam-heating apparatus; with it, it is possible to heat any character of building, in

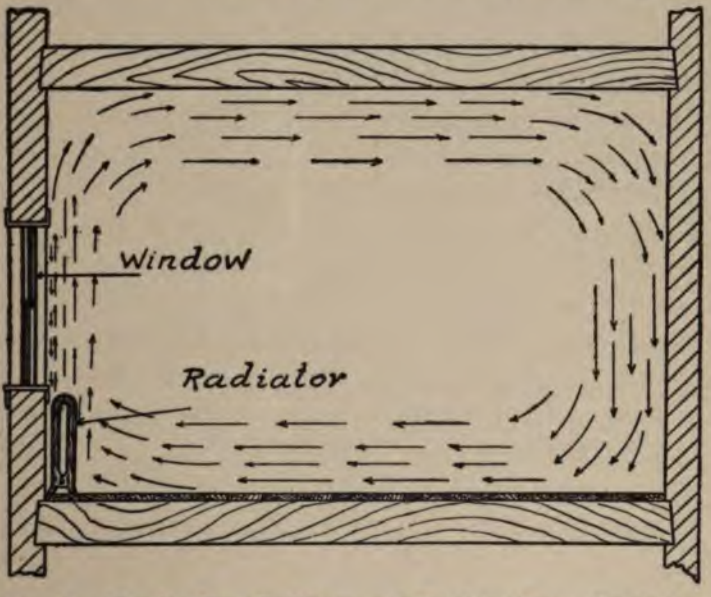


Fig. 13. Showing How Radiators and Windows Cause Circulation of Air in a Room.

any location, regardless of extremely low temperatures or prevailing high winds, so long as these conditions have been provided for by the heating contractor.

The early method of steam heating was in accordance with the **two-pipe system.** Many such plants, however, were noisy in operation, caused by **water-hammer** in the system, this con-

dition being due to the faulty installation of the small piping used; and such plants were also often rendered inefficient by poor practice in making pipe connections. Water-hammer is caused by the presence of traps in the piping; that is, portions of the piping system are imperfectly drained of the water of condensation. When the fire is checked, and the piping and radiators cool, the portion of the water of condensation which has found lodgment in the piping or the radiators has also become cold. When steam is again generated at the boiler, the supply in passing this accumulation of cold water in the traps or pockets condenses rapidly, and this action causes water-hammer. To overcome this trouble, it is therefore necessary that all steam piping, regardless of the particular system used, should be so erected as to insure perfect drainage in this respect.

In this connection the use of **eccentric fittings** is advised. Fig. 14 shows a short part of a main steam line on which the ordinary styles of fittings are used and the size of main reduced, and also the identical piece again on which fittings tapped eccentric are placed. The perfect drainage afforded by the latter usage is at once apparent.

The modern low-pressure system of steam heating is usually a gravity job, the boiler or steam generator being placed below the level of the steam mains. While the two-pipe system is still at times advocated and employed, prac-

tically all of the installations of low-pressure steam heating in these days are erected by what is known as the **one-pipe method.** There are

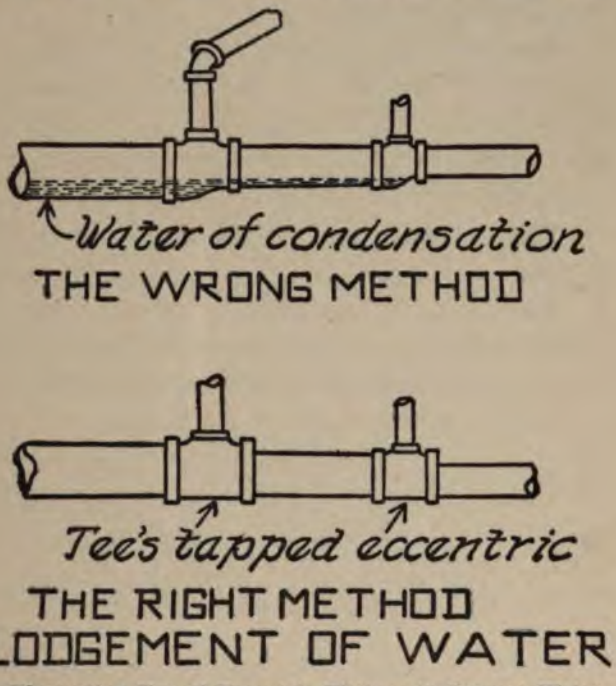


Fig. 14. Illustrating Use of Eccentric Fittings to Prevent Water-Hammer.

several adaptations of this method—namely, the "one-pipe circuit" system, the "divided-circuit" system, the "one-pipe system with dry returns," the "one-pipe system with wet returns," etc. These will be described later.

In planning for the installation of a low-pressure steam-heating apparatus, it is necessary to figure for each room to be heated the size of radiator needed to warm the space to the

required temperature; and after the total amount of radiation necessary for the work has been determined, the next step is the selection of a suitable boiler.

Methods of Determining Radiation. The amount of radiation required depends upon three prevailing factors: (1) the size and location of the room; (2) the square feet of its glass exposure (windows and outside doors counted as glass); and (3) the square feet of outside or exposed wall surface. Too many fitters and contractors are using "rule of thumb" methods in calculating such requirements, thereby causing trouble and unsatisfactory results from installations of this character. Only such rules as are absolutely accurate should be used in figuring on work, and the two known as the "Baldwin" and "Mills" rules can be relied upon.

Baldwin Rule. The Baldwin rule for determining radiation is as follows:

> Divide the difference in temperature between that at which the room is to be kept and the coldest outside atmosphere, by the difference between the temperature of the steam in the radiator and that at which you wish to keep the room, and the result will be the square feet of radiating surface to be allowed for each square foot of "equivalent glass surface."
>
> Count each square yard of exposed wall as a square foot of glass to determine the former's equivalent in glass surface.

For example, we shall consider a room 12x15 feet in size, with a 10-foot ceiling, containing

two windows 3x6 feet in size, and having one side wall (10x12 feet) exposed.

Temperature desired in room	70°
Outside temperature—zero	0°
Difference	70°
Temperature of steam in radiator at 1 lb. pressure	215.5°
215.5°—70° (temperature of room) =	145.5°
(Dif. in temperature) ÷ 145.5° =	.481
Glass in windows 3′ × 6′ × 2 =	36 sq. ft.
Equivalent glass in wall 10′ × 12′ ÷ 9 =	13⅓ sq. ft.
Total equivalent glass	49⅓ sq. ft.

49⅓ x .481 = 23.7 sq. ft. of radiation required.

The result from the above calculation provides only for the exposures named, and does not take into account the effect on the system from loose windows, poor building construction, or a degree of exposure excessive beyond that stated.

Mills Rule. The Mills rule, known also as the rule "2—20—200," is possibly more easily applied, and it is consequently the one generally adopted by heating men. Its explanation follows:

Find the following three quantities in each room to be heated: (1) the cubic feet of contents, by multiplying together the length, width, and height; (2) the square feet of exposed or outside wall (not deducting the space occupied by doors or windows); and (3) the square feet of glass (counting outside doors as glass). After obtaining these results, proceed in figuring thus:

For each 2 sq. ft. of glass, allow 1 sq. ft. of radiation; for each 20 sq. ft. of exposed wall, allow 1 sq. ft. of radiation; for each 200 cu. ft. of contents, allow 1 sq. ft. of radiation.

The total of these different results will be the number of square feet of radiation required to heat the room to 70° with a pressure of 2 lbs. of steam, the outside temperature being at zero.

For example, consider a corner room (two walls exposed) having three windows 3x6 feet in size. Dimensions of room, 15x20 feet, with a 10-foot ceiling.

$3' \times 6' = 18$ sq. ft. $\times 3 = 54$ sq. ft. of glass
$15' + 20' = 35$ feet $\times 10 = 350$ sq. ft. of exposed wall
$15' \times 20' \times 10' = 3{,}000$ cu. ft. of contents
$54 \div 2 = 27$
$350 \div 20 = 17.5$
$3{,}000 \div 200 = 15$

Total, 59.5 sq. ft. of radiation required.

For all direct-indirect radiation used, add 25 per cent to the amount to obtain the equivalent of direct radiation; and to the amount of all indirect radiation used, add 50 per cent to obtain its equivalent in direct radiation. The character and purpose of "direct-indirect" and "indirect" radiation are explained later under the heading "Radiating Surfaces."

Having determined the number of square feet of radiation necessary to heat the building in accordance with the above rules, we proceed to the selection of the boiler.

BLACKSMITH SHOP OF A LARGE SWITCH AND SIGNAL COMPANY.
A splendid example of good lighting and ventilation.

Selection of a Boiler. The selection of the proper size and character of boiler for any installation means much for the efficient and economical operation of the entire job.

The catalogue ratings of all boilers for house heating, or "low-pressure" boilers, are gross ratings; that is, in the stated capacities, not only is the amount of radiation to be supplied considered, but all pipe, fittings, etc., on the work are counted as radiating surface, and allowance must be made for the same in accepting the printed ratings.

House-heating boilers are the opposite of power (tubular) boilers in so far as the matter of fuel consumption is concerned. With high-pressure boilers used for power purposes, the point of greatest economy is reached by burning as much fuel as possible within a certain period for each square foot of grate surface; and this type, consequently, has a high rate of combustion. With low-pressure boilers, on the contrary, the greatest economy is afforded by a low rate of combustion, and with a heating apparatus we aim to burn as little fuel as possible per square foot of grate per hour.

House-heating boilers must be capable of running six or eight hours without attention, and be able during this period of operation to keep all radiating surfaces filled with steam.

Manufacturers' ratings, as a rule, are based upon evaporative tests; that is, that a certain number of pounds of condensation may be evap-

orated per pound of fuel per square foot of grate per hour. This amount varies from 7 to 10 pounds per hour, with an average of possibly 8½ pounds. A safe plan when using such ratings, is to make the following allowances:

Actual sq. ft. of radiation in building	600
Add 25 per cent for uncovered mains and risers	150
	750
Add 10 per cent for radiation in risers	75
	825

To this result should be added an allowance of 10 or 15 per cent for friction or loss of heat between the boiler and radiators, the final result showing that for good service on the work the boiler selected should have a gross rating of approximately 900 square feet.

For economy, choose a boiler so constructed that it may be easily and thoroughly cleaned in all its parts. Soot is a great non-conductor; and the heating surfaces, to be effective, must be kept free from an accumulation of it.

The firebox and grate provided are features worthy of particular attention, as a firebox of proper depth, and a type of grate which can be easily cleaned and which is able to carry its full load of fuel without a sagging of the bars, are essential points to consider.

A large amount of direct heating surface above the grate, with a length of fire travel suffi-

cient to consume and utilize the gases of combustion, means economy of fuel.

Cast-iron boilers are used to a greater extent than wrought-iron constructions for low-pressure heating purposes, as experience has conclusively demonstrated that cast iron is slow to corrode or rust, is easily moulded into any desired shape, and is most efficient in absorbing the heat units from fuel consumed.

Do not select a boiler having packed joints, as it will dry out and leak at these points. Iron to iron connections made with push or screw nipples are the best.

Finally, select a boiler made by a company or firm of unquestioned business standing. Such a concern will make good any defects of manufacture which may develop in their product and for which they can be considered responsible.

One-Pipe Circuit System. The one-pipe circuit system of steam piping is doubtless used more than any other plan, as it is the one having the most advantages when installed in a square or rectangular building.

In this system, the upright pipe out of the boiler rises to as high a point as possible, up to within a few inches of the cellar joists. On its top is placed an elbow from which the circuit is started. This starting place is the high point of the main steam pipe; and from it the main should have a gradual fall or pitch from the boiler of one-half inch to one inch in each ten feet of length. The branches should pitch up

from main at least one inch in each five feet of length, and as a rule should be of one size larger pipe than are the risers which they feed.

The circuit continues around the basement at a distance of from three to four feet from the outside wall, continuing until an advisable point

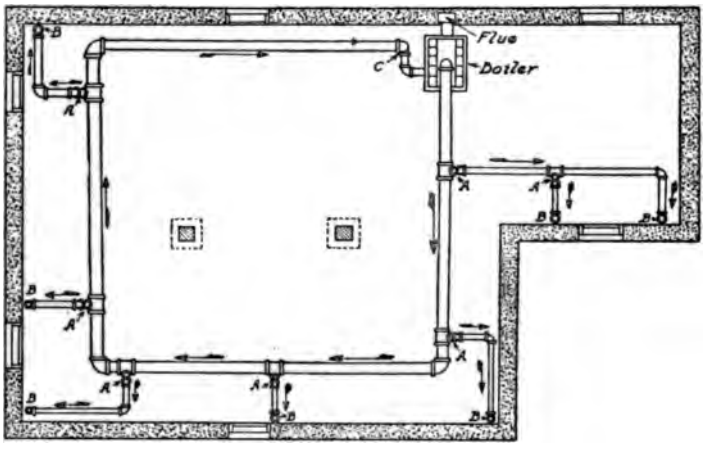


Fig. 15. One-Pipe Circuit System of Steam Heating.

at or near the boiler is reached, where a reducing elbow is placed on the end of this main, and a drop made with a smaller size of pipe into the return opening of the boiler.

Fig. 15 shows the basement plan of a piping job of this character. The main acts as a reservoir supplying the various branches leading to the radiators, and also as a return pipe receiving the condensation from the various branches it feeds. By reason of this latter function, it should not be reduced, but should be run full size from the boiler to the end where the return

connection is made. The condensation from the system runs along the bottom of the main in the same direction as the course of the steam. Fig. 16 illustrates three views of a main of this character, showing the extent of the reduction in its area due to the space occupied by the condensation; a designates the main as it leaves the boiler; b, the same main after the condensation

Fig. 16. Sectional Views of a One-Pipe Circuit Steam Main at Different Points.

from several branches has been returned to it; and c, this main at a point near to the return connection, showing possibly one-quarter of its area occupied by the condensation.

At the extreme end of the main, where the connection to the return is made, there should be placed an automatic air-valve, in order that all air in the main may be quickly exhausted, and the main put in shape to be rapidly filled with steam so that all branches will be supplied at practically the same time, thereby securing an equal proportion of heat from all radiators.

Each branch connection may be taken from the main by either of two methods—namely, (1) by using a nipple and 90-degree elbow, as

illustrated in Fig. 17; and (2) by using a nipple and 45-degree elbow, as illustrated in Fig. 18.

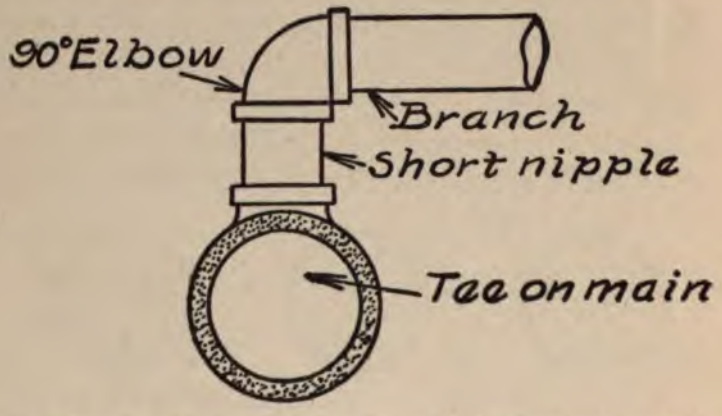


Fig. 17. Branch Connection to Steam Main by Nipple and 90-Degree Elbow.

The method shown in Fig. 18 is preferred for the reason that in all low-pressure mains the

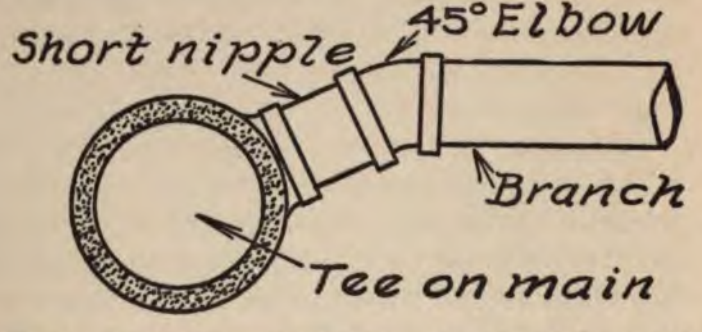


Fig. 18. Branch Connection to Steam Main by Nipple and 45-Degree Elbow.

steam flows along the top, the condensation along the bottom. With the 45-degree connection, the condensation from each branch enters

the main without saturating the steam, while with the use of the 90-degree connection this water of condensation flows into the main on top of the steam supply, saturating it and thereby greatly reducing its efficiency. This difference is very clearly explained by Fig. 19.

Points marked **A A A** on Fig. 15 indicate the 45-degree connection; **B B B**, the risers to radi-

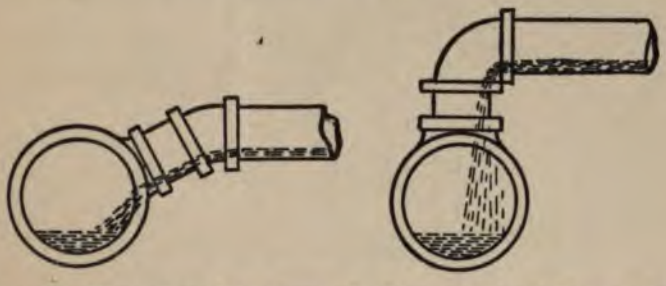


Fig. 19. Illustrating How Steam Is Saturated by 90-Degree Connection to Main.

ators; and **C** the point at which the automatic air-valve should be placed. The arrows indicate the downward pitch of the main and the upward pitch of the branches.

On all low-pressure steam work, the velocity of the steam through the riser out of the boiler should be materially less than that provided in the main. To accomplish this result, it is well to have the riser of one or two sizes larger pipe than that used for the main, placing a reducing elbow at the top to start the main.

The end of the steam main should never be lower than a point 14 inches above the water-line of the boiler; and, if possible, a distance of

20 inches should be maintained between the two points. Fig. 20 shows an elevation of the boiler and return connection of a piping system as shown in plan in Fig. 15, and clearly indicates

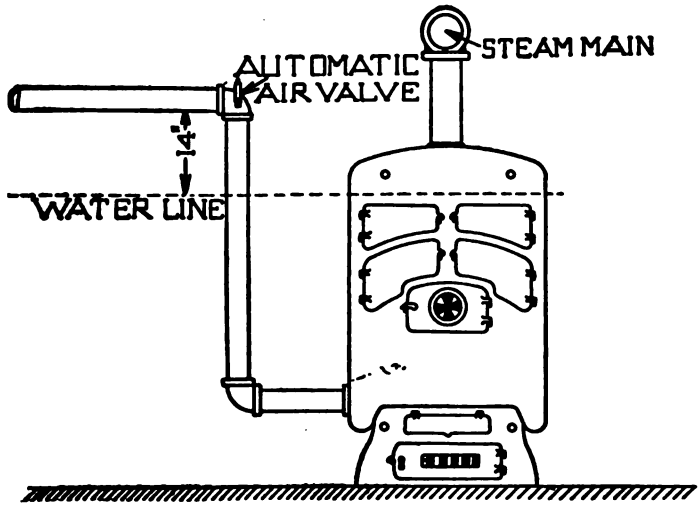


Fig. 20. Elevation of Boiler and Return Connection of a One-Pipe Circuit System of Steam Heating as Shown in Plan in Fig. 15.

the space to be maintained between the end of the main and the water-line of the boiler.

Divided-Circuit System. The divided-circuit or two-circuit system is quite similar in its general plan to the single-circuit, and what has been said regarding the details entering into the one will apply to the other. When the boiler is located on one side of a rectangular building, frequently it is better practice to run the main in two circuits; and the method this provides is known as the **divided-circuit system.** On

leaving the boiler, the mains pitch down from it in either direction, following around the basement until they meet at the side opposite to the boiler, or perhaps at some other point, the place of junction depending upon the character of the building or on circumstances surrounding the

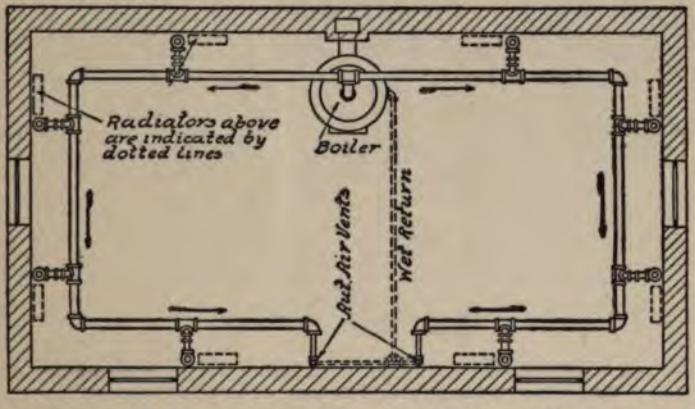


Fig. 21. Divided-Circuit System of Steam Heating.

installation. At this point a reducing elbow and an automatic air-valve are placed on the end of each main, and a drop made to the floor of the basement, where, below the water-line, these returns are connected together, and a single pipe having a capacity equal to that of both the drop pipes is run across the cellar floor, either on the surface or under it, to the boiler, where it is connected into the return opening.

As the ends of the mains or circuits are usually some distance from the wall, it is not advisable to drop directly at this point, but preferable rather to carry the pipe to the wall, and then drop.

Fig. 21 illustrates the divided-circuit system; and Fig. 22, the method of connecting the returns together below the water-line of the boiler.

One distinct advantage of a one-pipe circuit system is that all piping is overhead and out of the way. In addition it affords a very neat and

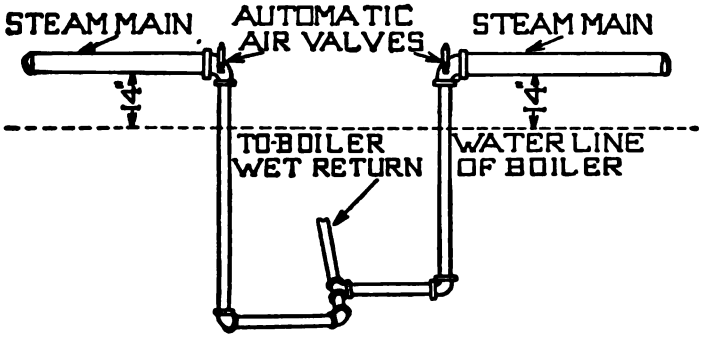


Fig. 22. Method of Connecting Returns below Water-Line of Boiler in Divided-Circuit System of Steam Heating.

attractive method of piping, and will be found sufficiently effective provided care is exercised in properly proportioning the sizes of the pipes. Pipe sizes for one-pipe systems are given in Table II.

One-Pipe System with Dry Returns. The one-pipe system of steam heating is so called from the fact that there is but one pipe connection to each radiator, this pipe acting the dual role of flow and return. For this reason the use of this arrangement requires pipes larger in size than those necessary for the two-pipe system. There are several adaptations of the one-pipe method, that illustrated in Fig. 23 being the one

particularly suited to a long narrow building where the main flow pipes may be run straight from the boiler in either direction.

The high points of the steam main are the elbows on the risers leading from the boiler, and from this point the mains and returns should have a gradual fall, free from pockets and traps, toward the return opening of the boiler, this fall or pitch averaging not less than one-half inch for each ten feet of length of the flow or return. Unless the system is modified to meet certain unusual conditions, such as an uneven height of the basement ceiling or similar oddities in construction, there should be no reduction in the size of the main prior to making the connection to the return.

Note the manner in which this connection is made. The return pipe is always one or two sizes smaller than the flow, and the connection from main to return is accordingly made with two reducing elbows and a close nipple. Assuming the main to be 3 inches and the return 1½ inches in size; on the end of the main is placed a 3x2-inch elbow, into which is screwed a 2-inch close nipple. To the other end of the nipple is attached a 2x1½-inch elbow, into which the 1½-inch return is connected. Note two things particularly, relative to this form of connection —first, that the 3x2-inch elbow is turned up until the top side of the 2x1½-inch elbow is even with the bottom of the former size. This method assists in gaining headroom in the basement, at

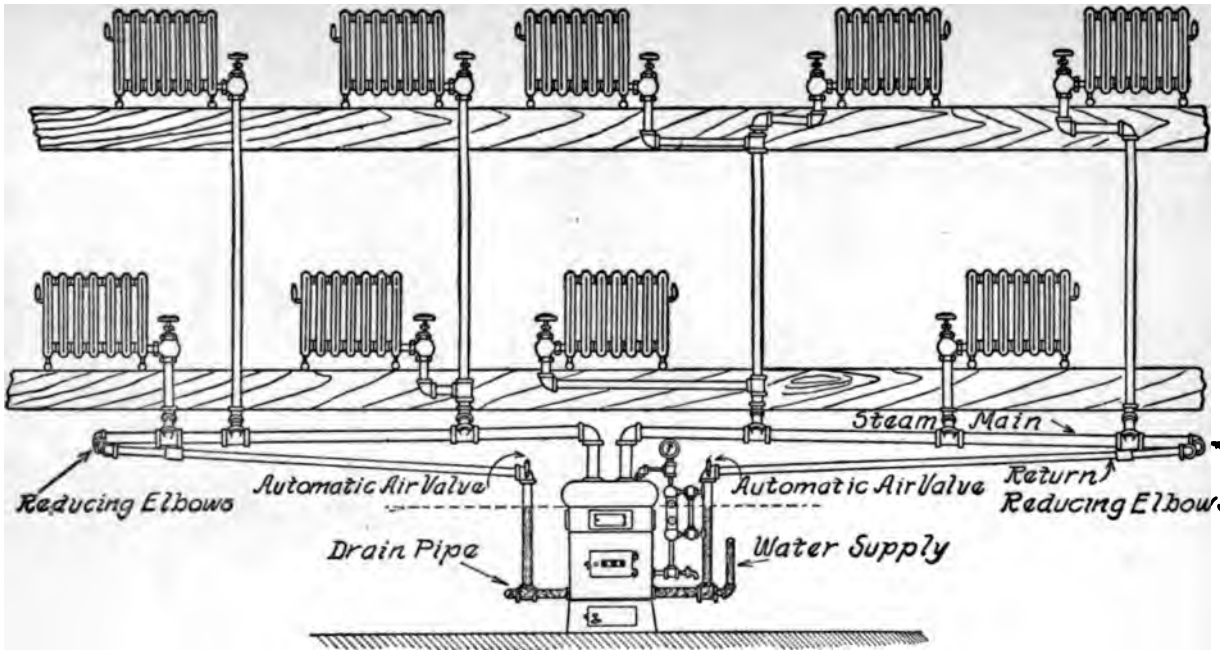


Fig. 23. One-Pipe System of Steam Heating with Dry Returns.

the same time permitting of the perfect drainage of the condensation from the main. Second, note that, should a length of pipe for the return be screwed directly into the 2x1½-inch reducing

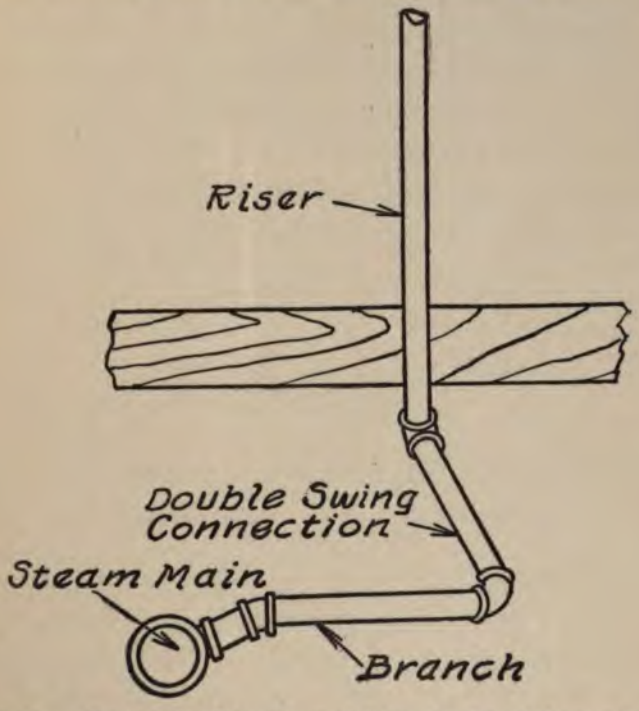


Fig. 24. Allowing for Expansion of Riser by Use of Swing Joint at Base.

elbow, it would extend out at a considerable angle from the main; and as it is desirable for the return to follow closely by the side of the main and just beneath it, it is necessary to use a short piece of pipe and a coupling with a crooked thread to throw the return straight with the main.

Where the elbow is placed on the end of the dry return for the drop connection into return opening of boiler, an automatic air-vent should be used, and this point should not be less than 14 inches above the water-line of the boiler, as previously described.

All branches are taken from the main with a 45-degree connection as shown in Fig. 18, and they should always pitch upward from the main

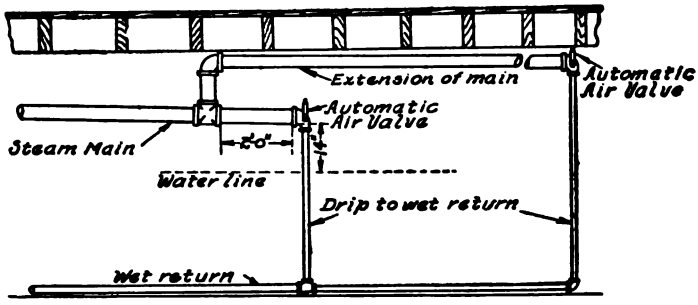


Fig. 25. Extension of Main in Building Too Long to Allow of Dry Returns Throughout.

at least one-half inch in each five inches of length. When supplying large radiators, the branches, as a rule, should be one size larger than the riser or radiator connection which they feed.

It is well to make connections to radiators in such a manner as will permit of some expansion of the riser. A swing joint at base of riser is sometimes employed for this purpose (see Fig. 24). When the length of a building is so great as to prevent the use of a dry return throughout the entire distance, it may be found imprac-

ticable to extend the main the full length of the building; and in such cases an extension of the main is made in the manner shown in Fig. 25, the size of the extension being governed by the square feet of radiation fed by it. Should it be required to supply only a few small radiators, it may drain back into the main in the same manner as any other branch connection. As a rule, however, it shows better practice to drip the end of this extension into a wet return, as illustrated.

In this connection we again call attention to the fact that the risers out of the boiler should be two sizes larger than the horizontal pipes which they feed.

One-Pipe System with Wet Returns. The one-pipe system of steam heating with wet returns does not differ materially from any one of the methods previously described so far as the manner of running the mains and connecting the branches is concerned. There are some heating men who favor a wet-return system, believing that the provision of the wet return steadies the working of the system or "balances" the job. This system is specially adapted to jobs where the mains are exceptionally long or when surroundings make it necessary to work unusually close to the water-line of the boiler.

A wet return would be started on a circuit job as soon as the last branch or radiator had been connected, but the drop should not be made directly at the last connection. The main should be extended not less than two feet beyond this

point where a reducing elbow tapped for an air-valve should be placed on the end, and the drop then made into a wet return. This return, as a

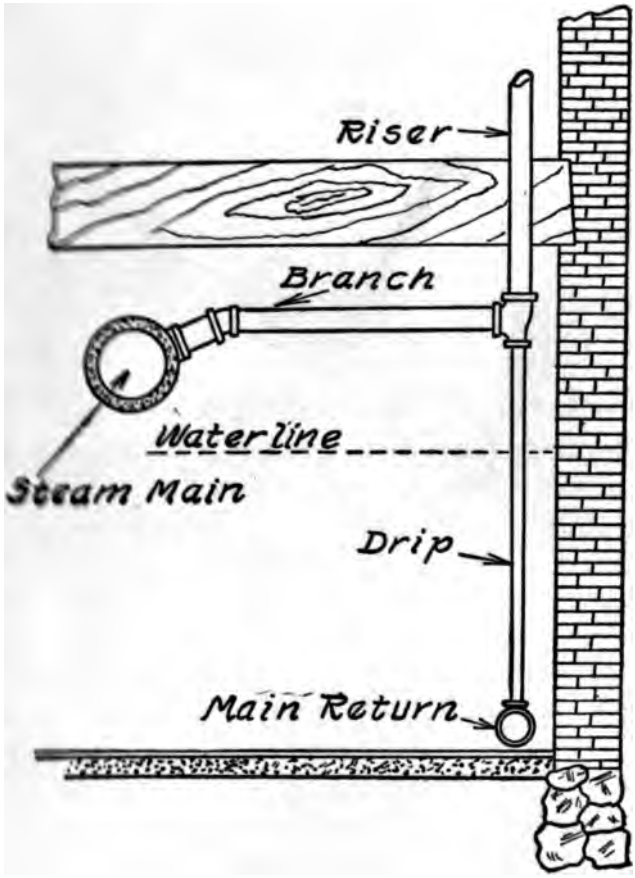


Fig. 26. Bleeding a Riser in Installing a Wet-Return System.

rule, is carried along the cellar wall to a point where a connection with the boiler can be conveniently made.

One method of installing a wet-return system

TABLE II

Sizes of Main and Return Pipes, One-Pipe System of Steam Heating
Boiler Pressure, 2 Lbs. Gauge

Sq. Ft. Direct Radiation	Size of Main	Size of Return
125 to 250 sq. ft.	1½ in.	1 in.
250 " 400 " "	2 "	1¼ "
400 " 650 " "	2½ "	1½ "
650 " 900 " "	3 "	2 "
900 " 1,200 " "	3½ "	2½ "
1,200 " 1,600 " "	4 "	2½ "
1,600 " 2,000 " "	4½ "	3 "
2,000 " 2,500 " "	5 "	3 "
2,500 " 3,500 " "	6 "	3½ "
3,500 " 5,000 " "	7 "	4 "

Note.—The maximum amount of radiation given for any size of pipe is based upon favorable existing conditions, such as a short main (under 100 feet) and a compact job. When mains are extremely long and the amount of radiation scattered, the larger size of pipe should invariably be used.

When direct-indirect or indirect radiation is placed, the sizes as given above should be increased on this basis: 25 per cent for direct-indirect, and 50 per cent for indirect.

The pipe sizes in the above table are applicable for use with either the single-circuit or the divided-circuit system.

is to bleed all risers, as illustrated in Fig. 26. If the job is of such a character that the risers can be treated in this manner, much smaller piping may be employed than is ordinarily necessary with one-pipe work, as no condensation enters the main from radiators or branches, and its entire area is free space for the conveyance of live steam. Also, where risers are dripped into the return in the manner illustrated, it makes no difference in the results attained whether a 45-degree or a 90-degree connection is used in starting the branch from main.

Sizes of Main and Return Pipes. Table II, giving pipe sizes for main flow pipes and returns, is based on a gauge pressure of 2 lbs. at the boiler. While some engineers consider the sizes as given somewhat excessive, the fitter can make

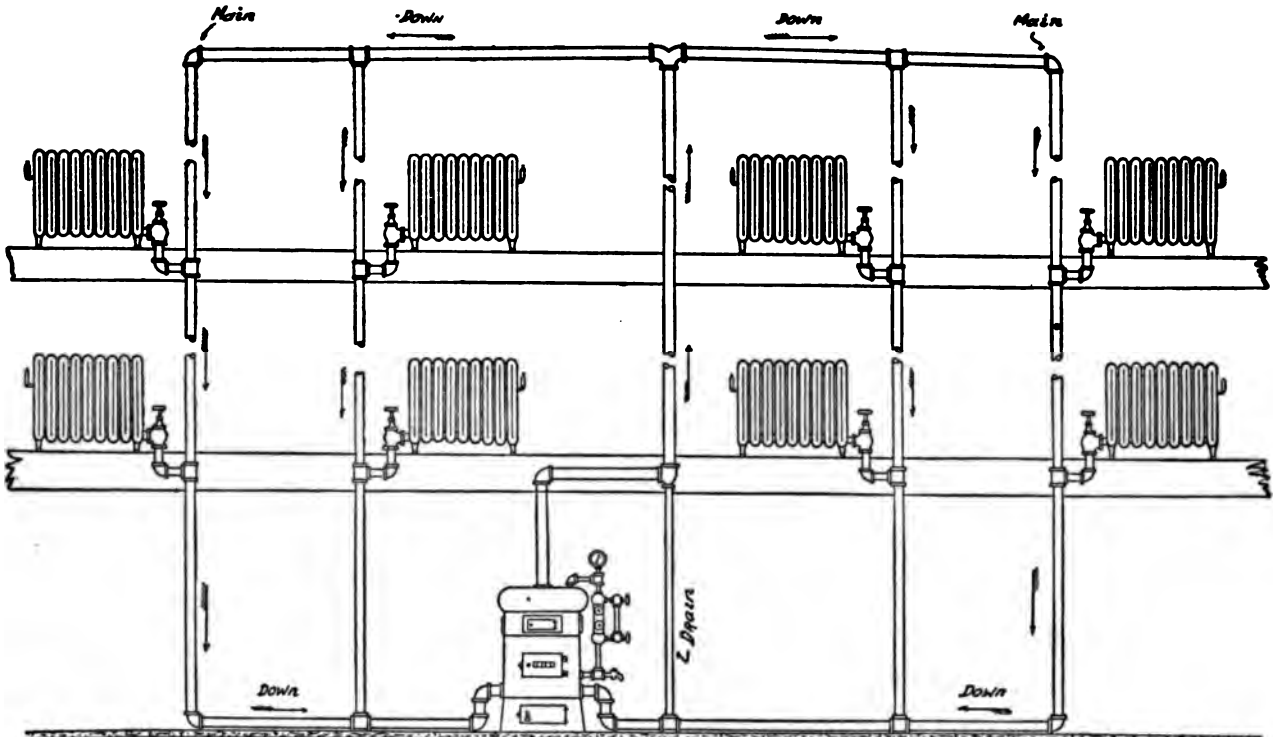


Fig. 27. General Design of Overhead System of Steam Heating.

no mistake by adopting them on heating work. Perhaps circumstances surrounding installations in some particular instances might warrant material reductions in the stated pipe sizes; but unless the fitter is fully conversant with the effect these conditions exert on the plant, it is better to be guided entirely by the sizes given, which have been proven by conclusive tests as worthy of general adoption.

Overhead System of Steam Heating. The overhead system, sometimes designated as the **Mills System,** is so called from the fact that all radiating surface on the job is supplied from overhead, or from a steam supply which has been taken directly from the boiler to the attic or an upper floor of the building, the main there dividing or branching to feed a number of "drops" or pipes extending through and connecting with the radiators on the various floors below.

Although styled the "Mills System," presumably so from the originator's name, Mr. Mills was not the father of the overhead idea in steam and hot-water piping. A Mr. Perkins, of London, England (1830), made use of it, as did also a Mr. Charles Hood at a somewhat later day, but prior to the advent of Mr. Mills.

Fig. 27 shows the general design of the system. The main steam supply is carried from the boiler to a point in the basement where it is convenient to rise with it to the top of the building. From this extreme end of the main riser,

which is the high point of the system, the distributing mains are taken, the number of the branches being as many as are necessary to supply the drops to the floors below. The attic mains and all branches pitch down from the high point named, in order that the entire system of piping may have a thorough drainage. The branches, as a rule, are taken from the side, as shown in Fig. 27. The drop pipes supplying radiators are connected in the basement into wet returns.

In so far as the mains and returns are concerned, the system is of the two-pipe style; that part relating to radiator connections is arranged on the one-pipe plan. The one-pipe systems described and illustrated in the preceding pages are largely used for small work. The overhead system is particularly adapted for heating a hotel, apartment, or other building of considerable height, where, by reason of the space on each floor being similarly divided, the radiators are placed in the same relative positions on each floor. A line of pipe or a drop can feed a number of such radiators so located without friction and with freedom from any of the water-hammer so prevalent in large installations erected in accordance with ordinary methods.

Although Fig. 27 shows a direct connection at the base of each drop, it is good practice to use an expansion joint at this point, or to allow for the expansion by making what is known as a **double-swing** joint, illustrated in Fig. 24. By

providing for expansion in this manner, a short, stiff connection may be used in connecting each radiator.

The attic mains should be hung on expansion hangers or supported by roller hangers in such a manner as to afford the pipes freedom to expand and contract. In order to understand the importance of this feature, Table III is given, showing the increase in length (or the expansion) of a line of pipe 100 feet long when heated to various temperatures.

TABLE III

Expansion in Pipe 100 Feet Long Due to Various Increases in Temperature

Temperature of the Air when Pipe is Fitted	Length of Pipe when Fitted	Length of Pipe when Heated to 215° — One Pound Pressure	Length of Pipe when Heated to 265° — Twenty-Five Pounds Pressure	Length of Pipe when Heated to 297° — Fifty Pounds Pressure
Zero	100 ft.	100 ft. 1.72 in.	100 ft. 2.12 in.	100 ft. 2.31 in.
32°	100 "	100 " 1.47 "	100 " 1.78 "	100 " 2.12 "
64°	100 "	100 " 1.21 "	100 " 1.61 "	100 " 1.87 "

From the information afforded by this table, it will also be readily understood how easily leaks may be caused in the system or fittings cracked from expansion when no provision for it has been made.

With this system, automatic air-valves are attached on each radiator in the usual manner. As the distributing supply is separate from the returns, and the steam and water of condensation both flow downward through the drops, friction is reduced to a minimum; and with this system, therefore, pipe sizes may be somewhat reduced from those required by the ordinary one-pipe method.

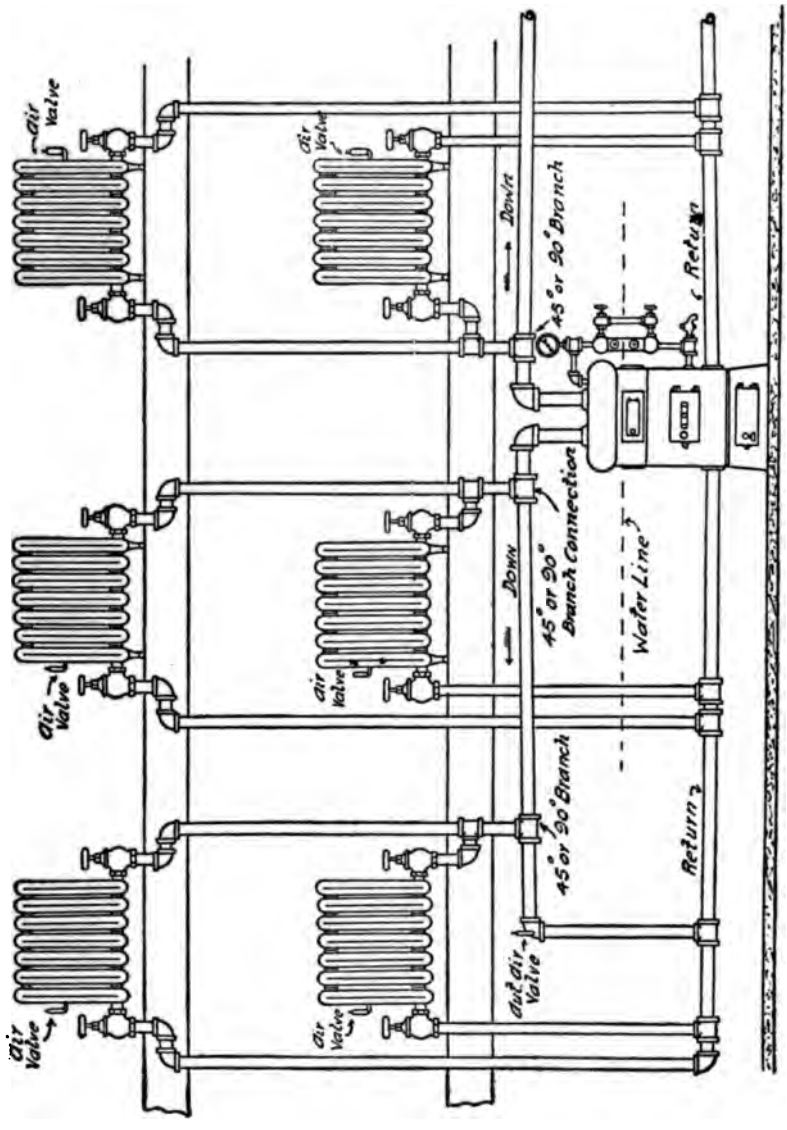


Fig. 28. Elevation of a Two-Pipe System of Steam Heating.

Two-Pipe System of Steam Heating. This is the oldest method extant, and while it is to-day practiced chiefly on high-pressure work, we find many such systems in use for low-pressure heating.

The piping for a system of this character may properly be, and usually is, somewhat smaller in size than that necessary for a one-pipe system, for the reason that the flow of steam and of the water of condensation are separated, each having its own service pipes. Fig. 28 is an elevation of a two-pipe system, and, from its examination, it will be noted that all return pipes are connected below the water-line of the boiler. This is an important feature to be observed in order to prevent the short-circuiting of the steam into the returns, which action would result in cutting off or retarding the flow of the condensation—a condition which might not only block the circulation but would probably also cause water-hammer.

Reference to Fig. 28 will show that two valves are necessary for each radiator or unit of radiating surface—one on the supply end, and one on the return end; and these valves should be operated in unison; that is, when the valve on the supply is opened or closed, the valve on the return should be opened or closed accordingly.

For the purpose of simple illustration, the risers are shown connected directly to the main. In actual practice, however, these should be in

every instance attached to the main with a swing or double-swing joint, the branches being taken from the main by either 45-degree or 90-degree elbow connections.

False Water-Line. It is sometimes necessary to place a job of this character in a building where a portion of the cellar is not excavated; and in order to follow the advisable principle of connecting the condensation into a wet return, it is essential to flood a return which would otherwise be dry. We call this arrangement the establishing of a **false water-line,** and the method practiced in doing the work is

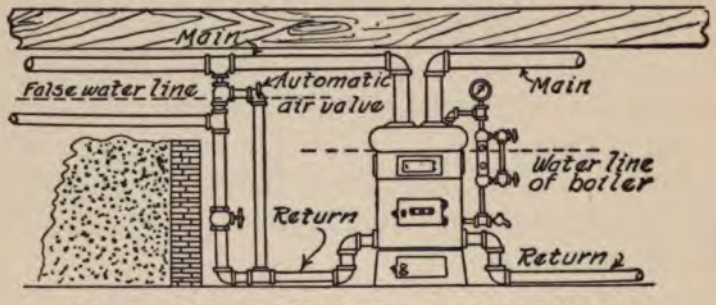


Fig. 29. Method of Establishing a False Water-Line.

clearly shown in Fig. 29. When the valve on the return (shown on sketch) is closed, the return will be flooded to the height of the loop, as indicated by the upper dotted line, the portion of the return pipe in the unexcavated section of the building remaining full of water. When it is necessary to drain the system, all water is expelled by the opening of this valve.

Steam Radiator Connections. In order prop-

erly to install a steam-heating plant, it is necessary to know what method of connecting radiators is best to use according to varying circumstances surrounding the installation. The ordinary form of stiff radiator connection from a

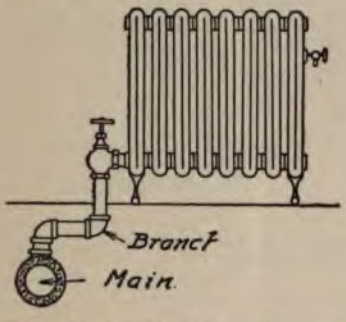


Fig. 30. Stiff Radiator Connection to Main.

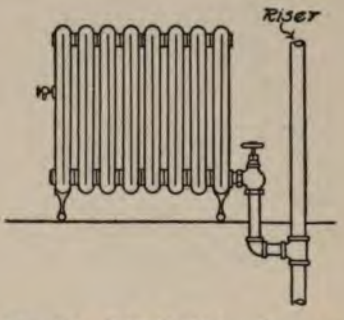


Fig. 31. Stiff Radiator Connection to Riser.

main is shown in Fig. 30; the same from a riser, in Fig. 31.

To allow for expansion, the radiator may be connected to the main by the style of branch shown in Fig. 32. When, in connecting a radiator to a riser, it is desired to allow the pipe to expand in an upward or downward direction, the tee on the riser should be turned to the side, and a close nipple and elbow used in making the connection, as illustrated in Fig. 33.

A two-pipe method of radiator connection, of which there are several adaptations, is shown in Fig. 34. If the riser is to expand freely, the connection to the flow end of the radiator may be made as shown in Fig. 33.

Radiators are sometimes placed on the wall

of the basement below the main but above the water-line of the boiler; and for the purpose of

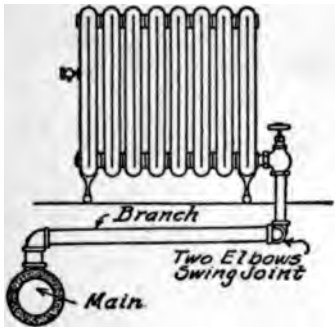


Fig. 32. Radiator Connected to Main So As to Allow for Expansion.

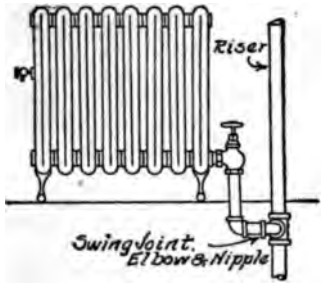


Fig. 33. Radiator Connected to Riser So As to Allow for Expansion.

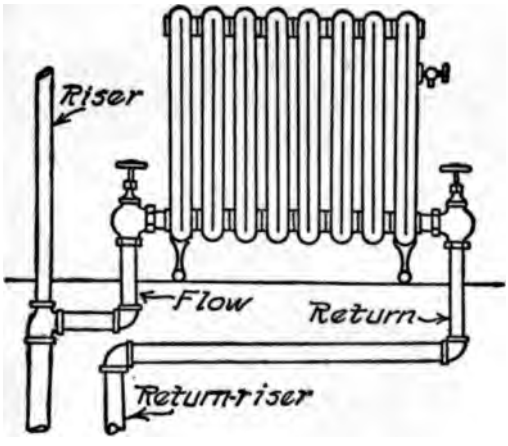


Fig. 34. Two-Pipe Radiator Connection.

such usage, a type constructed of flat panel-shaped sections is employed. These forms are known as **wall radiators,** and the method of connecting them is shown in Fig. 35.

If it is desired to make this connection in

such a manner that the condensation from the main will pass through the pipe feeding but

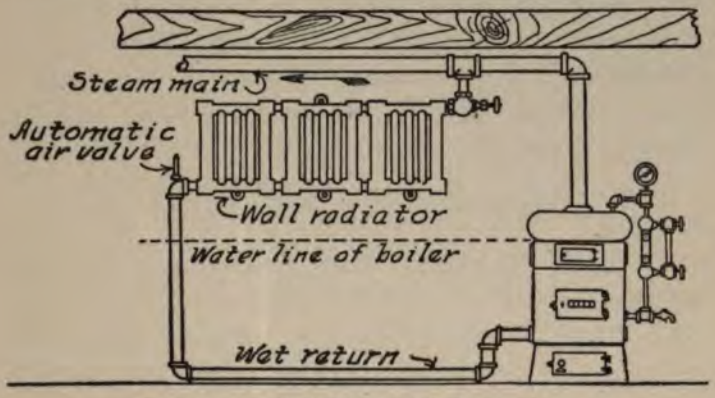


Fig. 35. Wall Radiator and Connections.

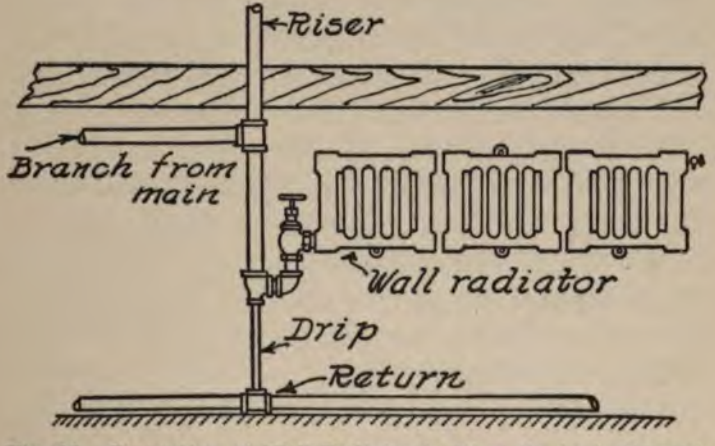


Fig. 36. Connection of Wall Radiator to Riser So As to Prevent Condensation from Main Passing through Radiator.

without going through the radiator, it should be attached as shown in Fig. 36, the branch being connected from the side or bottom of the main.

A little care exercised in the proper connecting of the radiators will often ensure a perfect working job. On the other hand, impractical radiator connections on the system, even though the general piping plan of the job be good, will inevitably make a poor and unsatisfactory job of steam heating.

HOT-WATER HEATING

There are to-day in vogue several systems of heating by hot water, and yet only two general fundamental principles may be said to be involved in all the various systems—namely, **gravity** and **forced circulation.** In the gravity systems, circulation is caused by the natural effect of gravity operating through the difference in weight of the water in the flow or ascending column and that in the return or descending column—that is, the difference between the specific gravities of the two columns, without which the water would not circulate. In the systems employing forced circulation, the water is driven or pumped through the system, the necessary power for this purpose being supplied by a centrifugal or rotary pump.

Hot-water heating is most frequently used in this country for the warming of residences, although it is often adopted also in buildings of larger size. The gravity principle is the one commonly used in residence heating, by reason of the simplicity of its system and the ease of management it affords. It is in the larger class

of buildings that the principle of forced circulation is generally practiced, owing to the size of the apparatus and the consequent extreme length of the mains or lateral supply pipes, and also by reason of the further fact that with this style of installation it is usual to supply a large number of radiators from a single riser.

We shall designate the two methods as **low-pressure** and **high-pressure.** With the low-pressure—the method commonly adopted—it is usual to carry the water in the system, in mild weather, at from 100° to 125° F., increasing the temperature as the weather gets colder to possibly 180°, which is the maximum degree allowed under the ordinary steam-fitter's test; in other words, the fitter is invariably asked to supply a heater and a sufficient amount of radiation to warm the building to 70° in the coldest weather, with the water at a temperature of not more than 180° at the heater. With the later type of **accelerated** or **assisted** systems of gravity hot-water work, the temperature may be carried to 240°, this equaling a pressure of 10 pounds on the system.

The heater used for low-pressure hot-water work is quite similar to the type of steam boiler already described, excepting that the steam space in the dome of the boiler is omitted in water constructions, and the internal waterways are sometimes (as they always should be) made smaller. The same features of construction essential to the production of a good, efficient

steam boiler must necessarily be included to secure a good hot-water heater. The circulation of the water within the heater itself should be positive throughout, and as nearly vertical as possible.

There are three general methods of piping employed in the installation of low-pressure hot-water work—namely, the ordinary **two-pipe system**, the **overhead system**, and the **circuit system**, which are described in detail in succeeding pages.

To the steam-fitter or mechanic about to install a low-pressure system, a few words of caution regarding some features surrounding the work are advisable:

First, the greatest care should be exercised in properly grading the piping as to size and pitch.

Second, it is of the utmost importance that the proper type of pipe connection be used at each point on the piping, for it is an old axiom among heating men that "as a circulation is once established, so will it continue." For example, if either one of two radiators supplied from the same pipe connection should receive the full circulation, the other would be "robbed" of its supply and thereby prevented from doing its share of the work; and this unsatisfactory condition will continue until the form of connection is changed.

Third, provision must be made for extracting any accumulation of air from the system, and for keeping the system always as free as possible from air, which is regarded as the arch enemy of the heating man. A pipe or radiator air-bound is out of active service, as water will not circulate through any portions of the system in this condition.

In view of the above information, it is impossible to give too much care and attention to the usage of the various forms for connecting and venting the expansion tank and the radiators on a system of hot-water heating.

To estimate the amount of direct hot-water radiation required to heat a building properly, proceed exactly in the manner already described for determining the quantity of radiation necessary for steam heating; and to the result obtained according to that rule, add 60 per cent. For example, suppose we find that 450 square feet of steam radiation would be required on the installation. Then, 60 per cent of 450 is $450 \times .60 = 270$. Adding this to the 450, we have $450 + 270 = 720$. That is, 720 square feet of direct hot-water radiation will be needed to do the same work.

When providing for indirect radiation in hot-water heating work, it is necessary to figure still stronger in proportion than on a steam job, and 75 per cent should be added to the amount of direct steam radiation in order to determine the square feet of indirect hot-water radiation required to do the same work.

To calculate the size of heater required for hot water, proceed in exactly the same manner as before described for determining size of steam boiler.

Note that for a steam-heating plant we use the term "Boiler" to designate the source of heat supply, as distinguished from the term

"Heater" for a hot-water apparatus. The distinction is made because of the fact that in generating steam we must "boil" the water; while for hot-water heating we do not boil the supply, but simply "heat" it.

Two-Pipe System. The two-pipe or double-main system is the ordinary or common style of piping adopted for hot-water heating. It is the oldest of the several methods to-day in general use; and notwithstanding the fact that many new ideas in hot-water circulation have been evolved from time to time, the two-pipe system is still the most favored plan of piping practiced on a hot-water job.

New ideas applied in the installation of this system, including revised methods of making the various pipe connections, have vastly improved its operation. Some years ago it was the general custom, when erecting such work, to use a large number of flow pipes—one independent supply to each group of radiators, with a corresponding separate return pipe—with the result that frequently as many as ten or twelve 1½-inch or 2-inch flow and return pipes were run on a residence job of ordinary size.

Experience has shown that the amount of friction in one large pipe is much less than that encountered in the number of small pipes necessary to afford the same area; and as a result, we now seldom use more than two flow pipes of the proper size on a job of average proportions. To get the best service from a given amount of fuel,

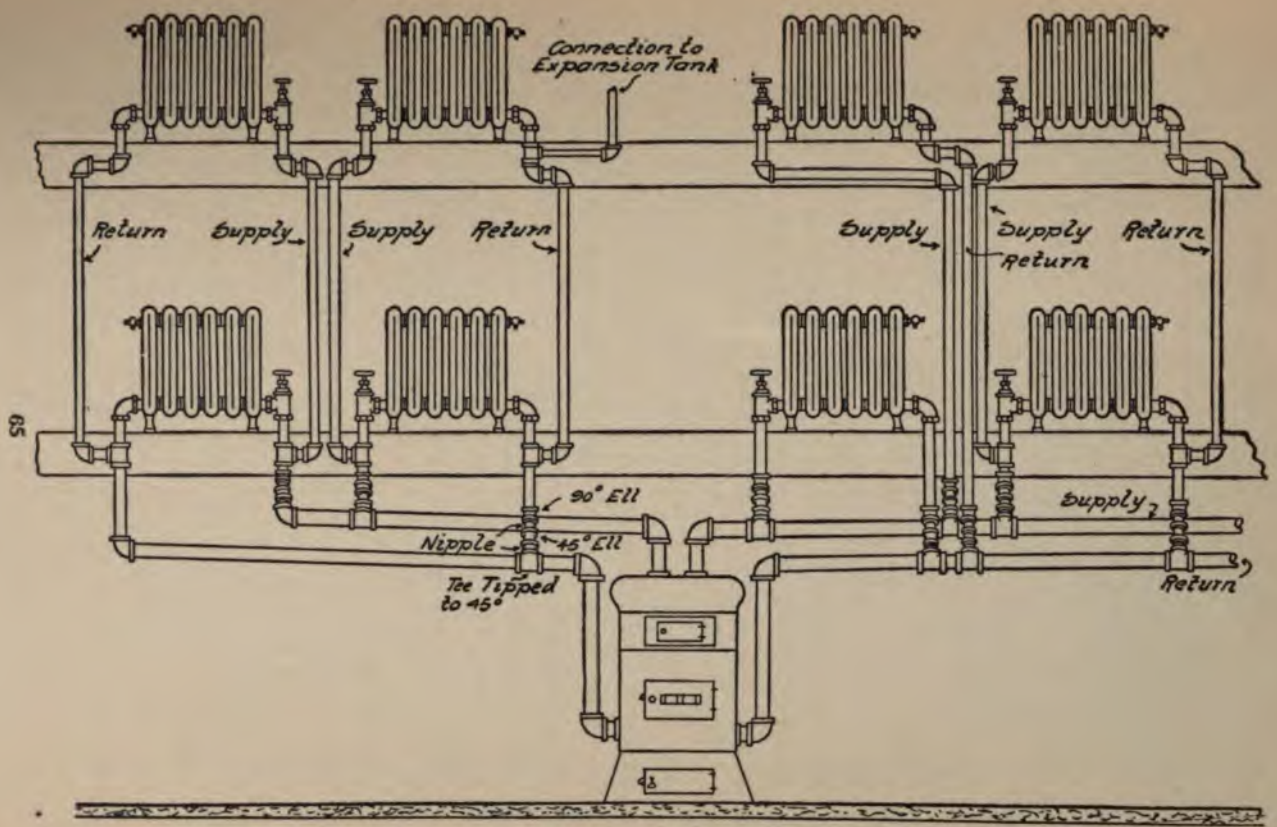


Fig. 37. Elevation of a Two-Pipe System of Hot-Water Heating.

it is necessary that friction in circulation be reduced to a minimum.

The flow pipe or pipes are started at a point above the heater, from such a height as will allow of an upward pitch to the main or mains to the extreme end of the system. The degree of this pitch should approximate one inch for each ten feet of length; and each branch from the main should pitch up from the main one inch in each five feet of length. Each flow pipe when starting from the heater is of a size sufficient to feed all of the branches supplied by it; and each such supply is gradually reduced in size as the various branches are connected, until, at the end of the line, it is but one size larger than the riser or radiator connection which it feeds.

Fig. 37 is an elevation of a two-pipe system. The main flow and returns are run parallel to one another, with a sufficient distance between the pipes to admit of applying pipe covering. The branches, as a rule, are taken from the main by the use of the 45-degree connection, in the same manner as for one-pipe steam work, although, when a branch supplies only upper floor radiators, it is good practice to take the line from the side of the main. As a rule, the return branches should be connected into the side of the main return.

It was a former practice of many fitters to take the branches from the top of the main; but, since each direct right-angle turn as afforded by a 90-degree elbow and top main connection in-

creases the friction in the circulation, this method has been largely discontinued. The general view of this system shown in the basement plan of piping, Fig. 38, will possibly prove more clearly illustrative of the system. The course of

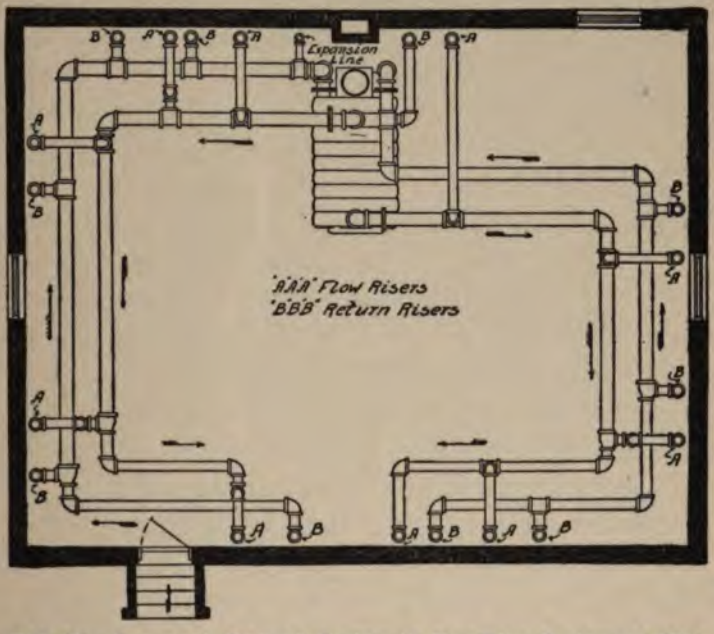


Fig. 38. Basement Plan of Piping in Two-Pipe System of Hot-Water Heating.

the circulation is indicated by the arrows, which show the supply of hot water from the heater flowing towards the radiators, and the cooler return water flowing back to the heater to be reheated.

Heating engineers are agreed on the point that the hotter the water when it returns to the heater, the more quickly the supply is reheated

and again put in circulation through the flow pipes. Therefore, to the owner, this heated condition of the return water affords increased efficiency and economy in comparison with an apparatus in which, owing to a poor arrangement of piping, the flow is so retarded as effectually to cool the water while traversing the system.

As water is heated from 40° to 212° it expands, gradually becoming more bulky, the degree of expansion approximating one twenty-fifth of its volume. When used for heating, it is necessary to provide some means whereby the supply may freely expand and contract without admitting air to the system. To provide for this condition, a small tank, called an **expansion tank,** is used, in which the water may rise and fall without in any way interfering with the heating system. This receptacle should be located at a point not less than three feet above the top of the highest radiator, and it may be connected to the return pipe from one of these highest radiators, or directly into the return at the heater. The pipe connection from the tank to the apparatus is called the **expansion pipe** or **expansion line.** A vent pipe, which is usually taken through the roof of the building, must also be carried from the top of the tank to the atmosphere, this outlet providing a necessary overflow.

Expansion Tank Connections. Of the three distinct methods of connecting the tank, Fig. 39 shows the one most commonly adopted. This

method does not provide for the warming or the circulating of the water in the tank; and therefore, when this type of connection is used, it is always advisable to place the tank in a warm room or protected position, in order to prevent freezing and a consequent sealing of the system, which might result in the generation of an excessive pressure likely to cause an explosion or similar injury to the plant.

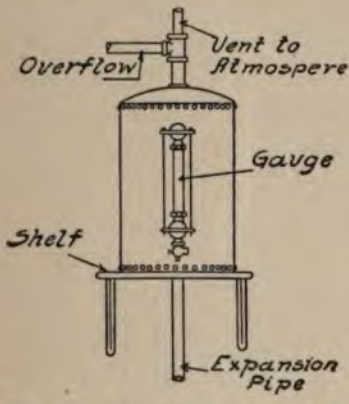


Fig. 39. Common Method of Connecting an Expansion Tank.

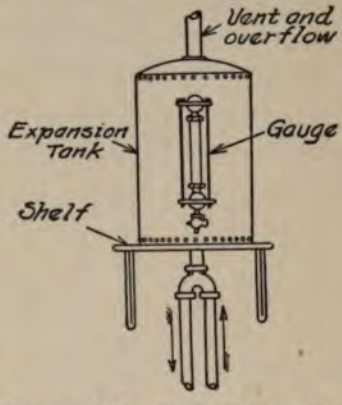


Fig. 40. Expansion Tank Connection to Provide Circulation of Hot Water and Prevent Freezing.

Fig. 40 shows the method practiced for circulating the hot water to the tank, this connection being employed when the expansion pipe runs through a cold wall or room, with a consequent liability to freezing.

When it is necessary to place the tank in a cold spot, some provision should always be made for circulating the water within it. One method of accomplishing this result is illustrated in Fig.

41. A tank connected in this manner has no possible chance of freezing.

Expansion tanks are made in certain standard sizes. Table IV shows the sizes and capaci-

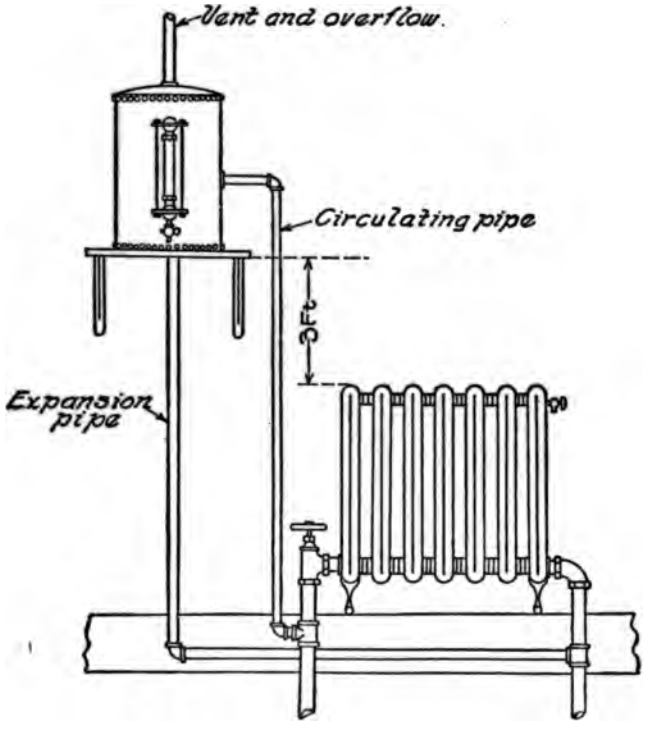


Fig. 41. Method of Connecting an Expansion Tank to Provide Circulation and Obviate All Danger of Freezing.

ties of different tanks and the proper size to use for certain specified work.

Frequently it is desired to arrange the apparatus so that hot water may be drawn from the system in an advantageous manner. In such a case, if the regular form of tank were

TABLE IV

Expansion Tanks

Size of Tank	Capacity	Square Feet of Radiation Provided for
12 x 20 inches	10 gallons	200 to 400
12 x 30 "	15 "	500 " 600
14 x 30 "	20 "	700 " 800
16 x 30 "	26 "	900 " 1,200
16 x 36 "	32 "	1,300 " 1,800
16 x 48 "	42 "	2,000 " 2,500
18 x 60 "	66 "	3,000 " 4,000

used, there would be danger of lowering the water below the top of the highest radiators, thus admitting air and blocking the circulation. To provide a suitable arrangement whereby a supply of hot water can be frequently drained

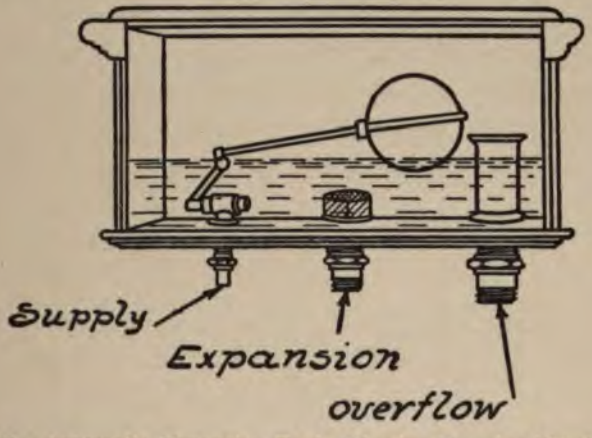


Fig. 42. Automatic Expansion Tank Allowing Drawing-Off of Hot Water from the System.

from the system without suffering the above disadvantage, an automatic tank of the type shown in Fig. 42 should be attached to the plant. The water supply to this tank is controlled by a ball-cock and float, which in operation admit water to the system as rapidly as any quantity is drawn

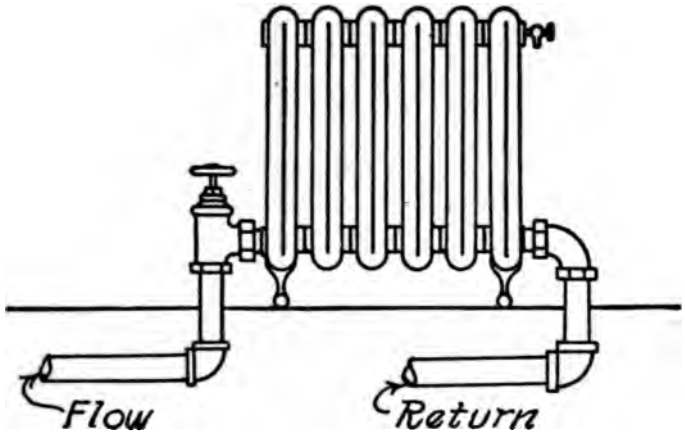


Fig. 43. Ordinary Method of Connecting a Hot-Water Radiator to Flow and Return Mains.

from it, the action being quite similar to that of the ordinary closet tank. No water-gauge is required on a tank of this character; and as the top is open, a vent is not necessary.

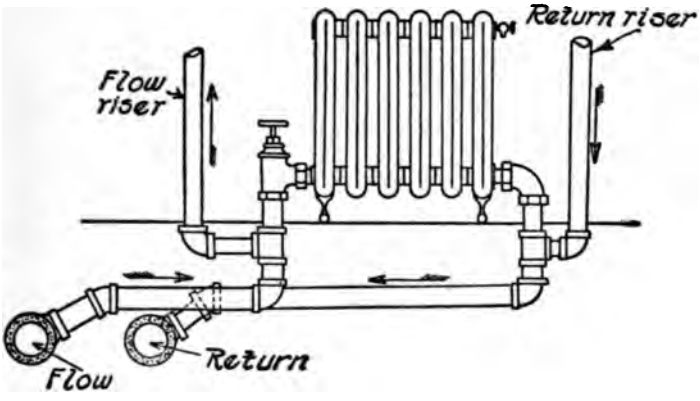


Fig. 44. Connections of First-Floor Hot-Water Radiator when Branch Feeds Also a Riser.

Hot-Water Radiator Connections. The usage of the double-swing or expansion joint, to which attention was called in discussing the connection for steam radiators, is not necessary in connecting a hot-water radiator; in fact, this type of connection is harmful, owing to the increased friction caused by the employment of

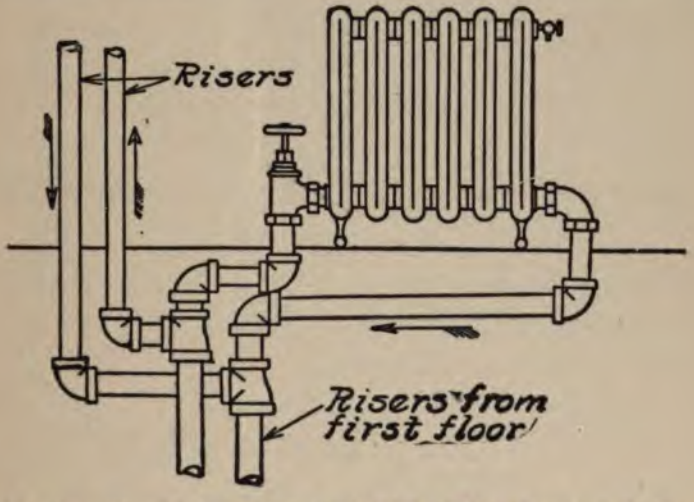


Fig. 45. Showing How Third-Floor Hot-Water Radiator is Connected to Side of Riser Feeding Second-Floor Radiator.

the extra elbows. Fig. 43 shows the ordinary method of joining a hot-water radiator to the flow and return mains, this connection being made in as direct a manner as possible.

When a branch feeds a first-floor radiator and a riser, the connection is made as shown in Fig. 44.

Where a second-floor radiator and a riser to floor above are connected, the third-floor riser is

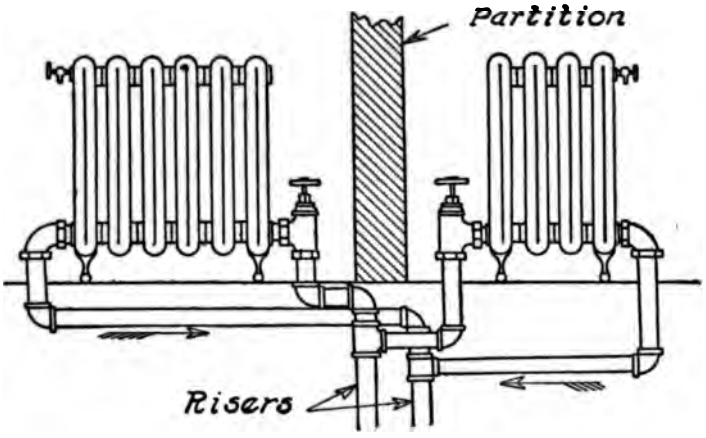


Fig. 46. Two Radiators on Same Floor Fed by a Common Riser—Larger Radiator Connected to Top, and Smaller to Side of Riser.

taken from the side of the one supplying the second-floor surface, as illustrated in Fig. 45. Note the application of the reducing tees on the riser.

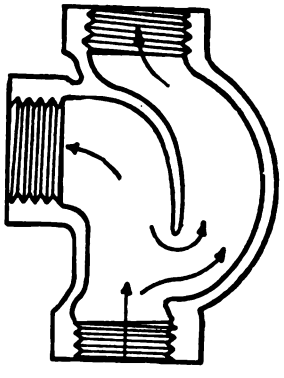


Fig. 47. O. S. Distributing Fitting.

When two radiators on the same floor are fed by a riser, the larger one should be supplied

from the top of the riser, and the smaller radiator from the side of the riser, as shown in Fig. 46.

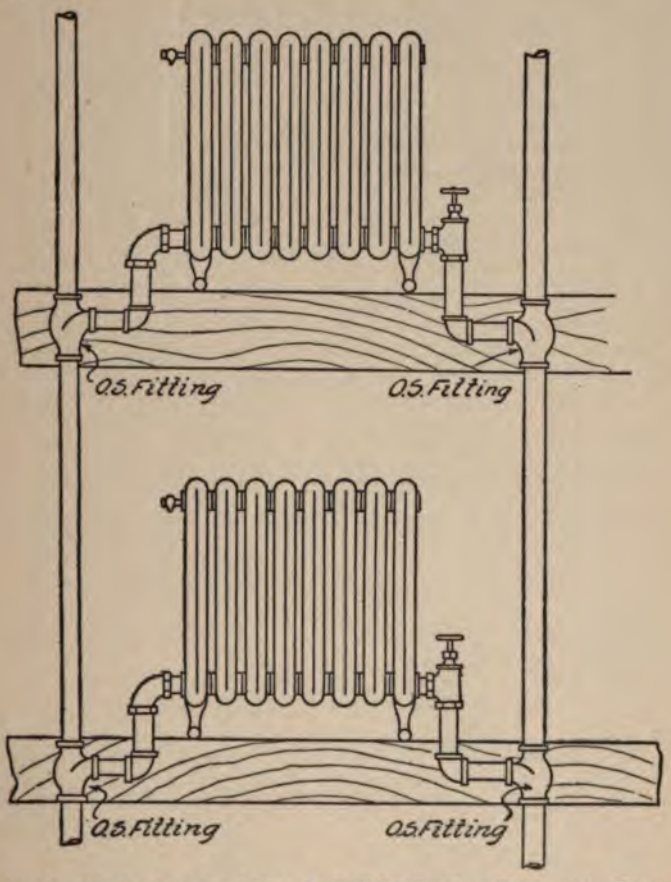


Fig. 48. Method of Applying O. S. Distributing Fittings to Risers.

The reason why the connections are made in the manner shown by the various illustrations, is that hot water in circulation has a tendency to flow quickly to the top of the system, and, by

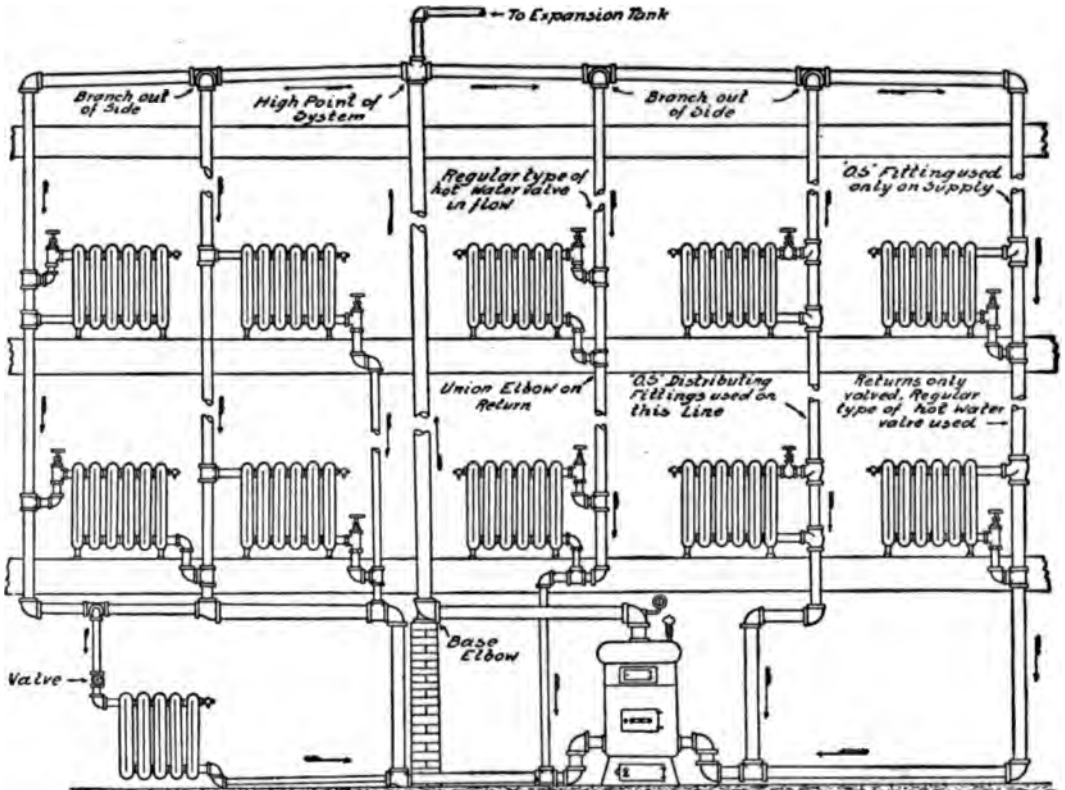

To Expansion Tank
Branch out of Side
High Point of System
Branch out of Side
Regular type of hot water valve in flow
'AS' Fitting used only on Supply
Union Elbow on Return
'AS' Distributing fittings used on this Line
Returns only valved. Regular type of hot water valve used
Base Elbow
Valve

Fig. 49. Overhead System of Hot-Water Heating.

taking risers to upper floors from the side of the riser which feeds them, there is a tendency somewhat to choke or impede the flow to upper floors, this arrangement thereby helping all radiators on the system to circulate evenly throughout.

A special fitting for use on risers, to distribute to each floor its proper share of the circulation, is known as the **O. S. distributing fitting,** illustrated in Fig. 47. The curved baffle-plate shown in the center of the fitting effectively divides the flow without friction. The manner of applying this fitting for use on risers is indicated in Fig. 48, and the neat appearance it affords will readily be noted.

Overhead System. The overhead system of hot-water heating is, in many respects, not unlike the overhead system of steam heating. The water is carried to the attic of the building, usually through a single pipe. The top of this main riser is the high point of the system; and from the fitting on this extreme end, the connection to the expansion tank is made. As the different pipes pitch upward to this point, all air in the system is here collected, whence it passes to the atmosphere through the expansion tank vent. By reason of this action, no air-valves are necessary on the radiators or on any other part of the system.

Fig. 49 will give a very clear idea of the adaptation of the system. At or from the top of the main riser, the various attic mains are

connected. These pitch down from the main riser, being run in the most convenient manner to supply the various drop pipes, which in turn feed the radiators on the several floors. Reference to the illustration will show several methods of connecting the radiators to the drop supply pipes. The one taken directly from the drop supply to the top of the radiator is the method most frequently used. By the usage of this top

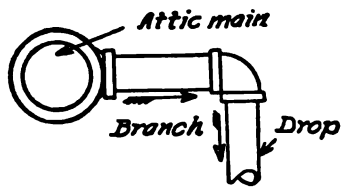


Fig. 50. Branch Connection to Attic Main in Overhead System of Hot-Water Heating.

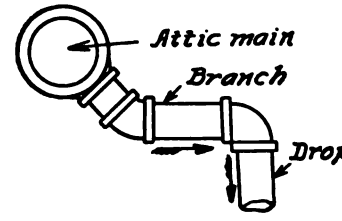


Fig. 51. Branch Connection to Attic Main in Overhead System of Hot-Water Heating.

radiator connection, the cooler water at the bottom of the radiator is returned into the drop supply pipe.

It is customary to carry the basement return pipes along the ceiling, connecting them together into the main return pipes in much the same manner as the supply branches of a one-pipe steam job are connected, with the exception that the hot-water return branches are connected into the side of the main returns.

If the radiators are required in the basement, it is necessary with this system, that the returns be carried back to the heater along the basement floor.

The branches in the attic are taken from the side of the main as indicated in Fig. 50, or from the bottom of the main at an angle of 45 degrees as shown in Fig. 51, inasmuch as connections

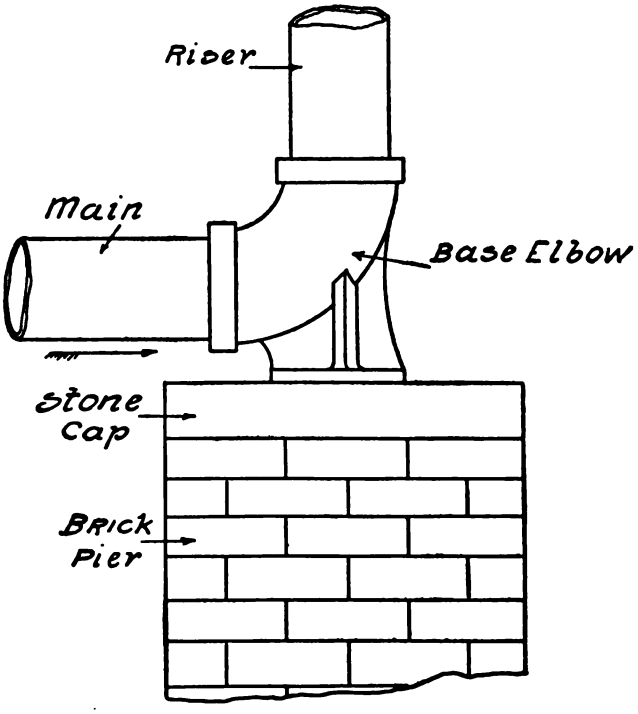


Fig. 52. Use of Base Elbow to Support Main Riser in Overhead System of Hot-Water Heating.

made in this manner prevent the formation of air pockets in the piping. The main riser should be supported either on a brick or stone pier or on a substantial wall in the basement, in order to prevent the sagging likely to be caused from the excessive weight it carries. A special elbow

called a **base elbow** should be applied at the bottom in the manner illustrated in Fig. 52.

To insure a neat-appearing job and at the same time afford the desired flexibility to the risers, the radiators should be connected with swing joints. With connections of this nature, the drop supply may be run close to the wall or partition, and nipples of such length used in the

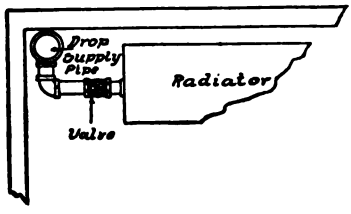


Fig. 53.

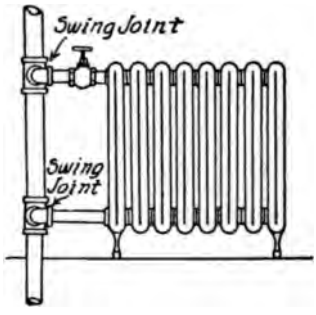
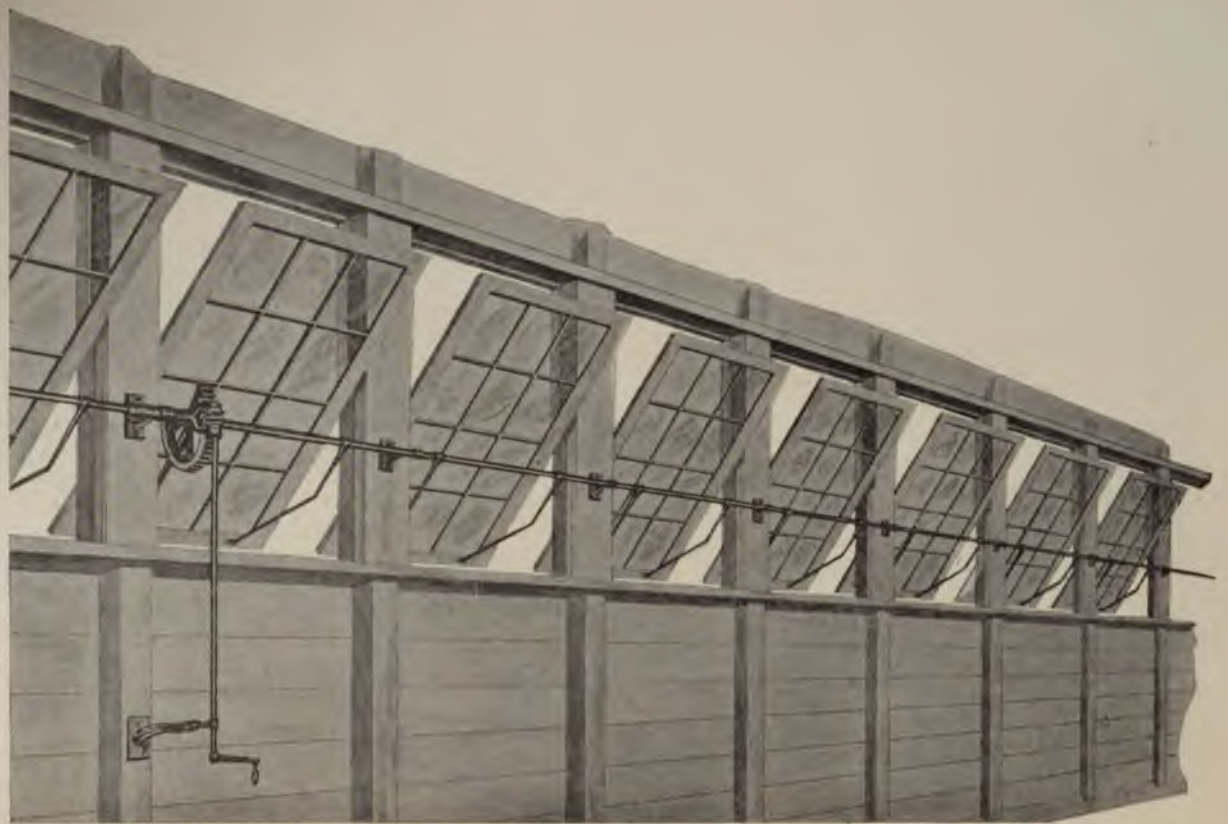


Fig. 54.

Plan and Elevation of Radiator Connected with Swing Joint to Riser to Allow for Expansion—Overhead System of Hot-Water Heating.

tees as will bring the centers of the elbows on a line with the centers of the openings in the radiators. A plan and elevation of this type of connection are shown respectively in Figs. 53 and 54.

The employment of the "O. S." fittings (described above) on the drop supply, in place of ordinary tees, will materially lessen the friction and divide the circulation to better advantage. The upper fitting in each instance is reversed, as indicated in Fig. 55.



SHOP VENTILATION.
Single row of side pivot-hung sash operated by worm and gear self-locking device.

Like the overhead steam system, the overhead hot-water system is especially adapted to large buildings where each drop may supply a

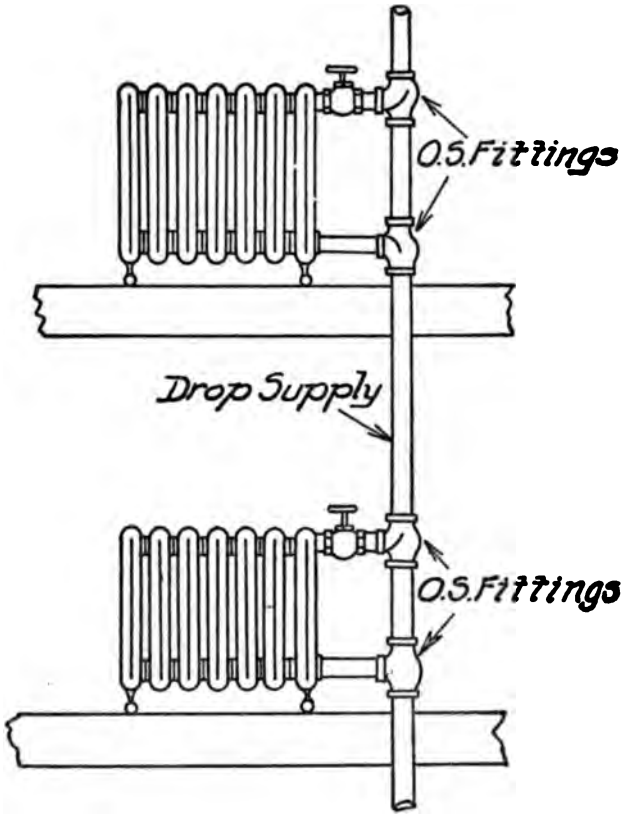


Fig. 55. Method of Using O. S. Fittings to Lessen Friction and Divide Circulation in Overhead System of Hot-Water Heating.

line of radiators on the various floors below. It is particularly positive in circulation, owing to the pressure developed by the weight of the water.

Circuit or Single-Main System. The one-pipe circuit system of hot-water heating has been widely used in America, particularly throughout the Western and Middle Western States, having found favor among many heating contractors and engineers; and while there is

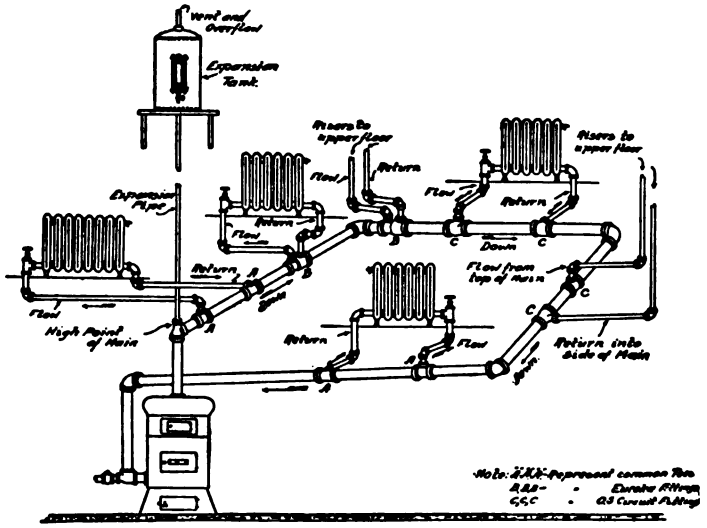


Fig. 56. Circuit or Single-Main System of Hot-Water Heating.

much that can be said in approval of this system, the elimination of some of its present features would add greatly to the advantages derived.

In this system a single pipe does the double duty of a flow and return main, in quite the same manner as a one-pipe steam main. Starting from the heater, this pipe rises to as high a point as the height of the cellar will permit, whence it has a gradual fall or pitch from the heater—

approximately one inch in each ten feet of length. The expansion tank is connected from the high point of the main above the heater. The flow branches are taken from the top of the main, the returns from the radiators entering the main at the bottom and traveling in the same direction as the flow of hot water. The return or cooler water, however, does not mix with the

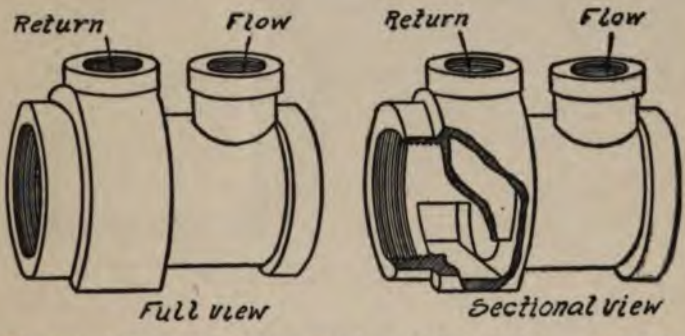


Fig. 57. "Eureka" Fitting, Used on Main to Improve Circulation in Circuit System of Hot-Water Heating.

hot water, owing to the fact that as the latter is lighter it hugs the top of the main.

Fig. 56 gives a general idea of the construction of this system and the manner of making connections to the radiators. There are several special fittings which may be used on the main to improve the circulation, one of which—the "Eureka"—is illustrated in Fig. 57. The broken view shows the interior arrangement providing for the return of the circulation into the main on its under side, through the bottom of the fitting. Fig. 58 shows a special style of tee having

top and side on a line, with outlets at the top and bottom; this device is known as the **Phelps Ideal Fitting.** The **O. S. Circuit Fitting** is shown in Fig. 59.

In Fig. 56, each of these special fittings is noted on the main; and we might say that one

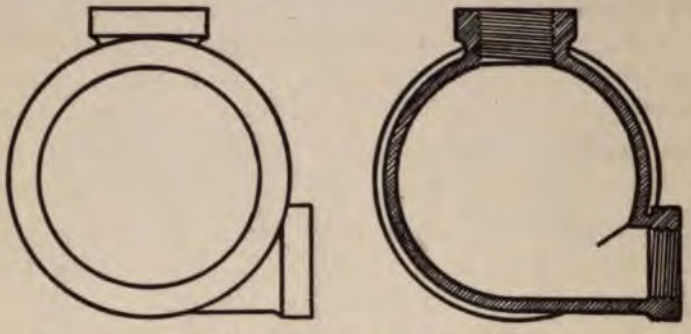


Fig. 58. "Phelps" Ideal Fitting.

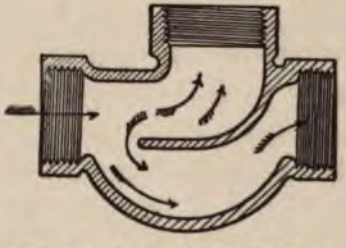


Fig. 59. O. S. Circuit Fitting.

advantage gained by their use is that a single fitting, as in the case of the Eureka or Phelps type, takes care of both flow and return branches, thus overcoming additional pipe cutting and the threading of the large pipe.

As the hottest water is that part of the supply nearest the heater, it is well, if possible, to

feed first those radiators which are located on the cold or exposed side of the building; otherwise, should the main be of any considerable length, it will be necessary to increase the radiation connected from the last leg of the circuit, in order to obtain desired results in that portion of the building.

When heating a church or similar structure, the usage of a large proportion of the piping and fittings which would necessarily be required on an ordinary installation may be avoided by adopting this system. Inasmuch, however, as residences are as a rule compactly built, the warming of homes can in general be better served with the two-pipe system.

Sizes of Mains for Hot-Water Work. The size of main necessary for an ordinary system of hot-water heating depends upon the size of all the different branches and the amount of radiation fed by each. Table V gives the minimum and maximum amounts of radiating surface which should be served by different sizes of mains.

TABLE V
Radiation Supplied by Hot-Water Mains

Size of Main	Amount of Radiation Supplied.
1½ in.	125 to 175 sq. ft.
2 "	175 " 300 " "
2½ "	300 " 475 " "
3 "	475 " 700 " "
3½ "	700 " 1,000 " "
4 "	1,000 " 1,400 " "
4½ "	1,400 " 1,750 " "
5 "	1,750 " 2,000 " "
6 "	2,200 " 3,000 " "

Where the quantity of radiation is scattered

—that is, composed of a large number of radiators—the size of main called for by the minimum amount is the proper one to select. Where the surface is compact, or divided into large units, the size indicated by the maximum amount is the correct main to use. With the gravity system of hot-water piping, open-tank generous-sized mains will afford the best service.

For a circuit job of hot water, use the size of main indicated for the minimum amount of radiation in Table V. For example, for 475 square feet of radiation, use a 3-inch main; for 1,000 square feet of radiation, a 4-inch main; and so on.

Pressure Systems of Hot-Water Heating. Heating by means of a forced circulation of hot water is not in general use in America. When adopted, it is principally in connection with large buildings, and in such installations many methods are employed. In numerous instances, hot-water installations have been under a pressure of from ten to fifteen pounds by the application of a safety-valve on the expansion tank, set to operate at this desired pressure. There is, however, an element of danger in this practice, for if the mechanism of the safety-valve should stick or for any reason fail to operate, an explosion of more or less disastrous consequences would in all probability result. Because of the risk involved, this practice, fortunately, has now been largely discontinued, especially since several mercurial devices have been placed on the

market which permit of the system carrying a pressure of eight or ten pounds without incurring any danger whatever.

On large installations where high-pressure steam boilers are used for manufacturing or mechanical purposes, certain systems of heating by a forced circulation of hot water can be adopted with good success. The principle involved requires a pumping of the return water through one or more heaters in which exhaust or live steam is employed for heating, the hot water being forced through the heating system by the pump, which may be of either the rotary or centrifugal type. Where plenty of exhaust steam can be obtained for the purpose, there is little or no expense in connection with this style of heating. The available heat units in the exhaust, after heating all necessary feed-water for the boiler, represent probably 80 per cent of its original value; in other words, with an allowance of 5 per cent for the requirements of the engine, and 15 per cent for the feed-water heater, there is left available for heating purposes probably 80 per cent of the heat units in the steam generated at the boiler. Where this proportion is not sufficient, live steam at a reduced pressure may be mixed with the exhaust in order to provide power to meet the requirements of the work. The pump receives the cooler return water, and forces it through the heater at a velocity of from 250 to 300 feet per minute, and at a temperature of about 200°.

Accelerated Systems of Hot-Water Heating. Systems of hot-water heating involving the use of special devices for accelerating the circulation of the hot water, have in recent years come into rapidly increasing popularity. The older

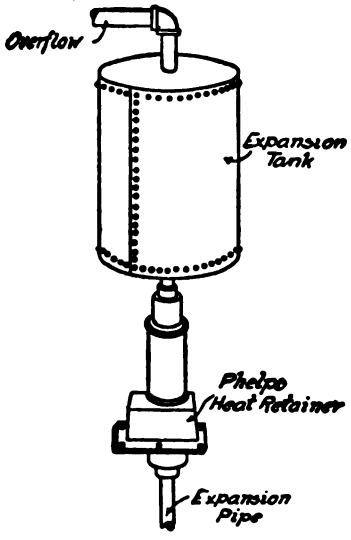


Fig. 60. "Phelps" Heat-Retainer.

of these special appliances for accelerating circulation are the **Phelps Heat-Retainer,** the **Honeywell Generator,** and the **Pierce Heat-Economizer.**

The **Phelps Heat Retainer,** illustrated in Fig. 60, consists of a double-acting valve enclosed within an iron box which is placed on the expansion pipe between the tank and the heating system. The valve disc, opening toward the expansion tank, is weighted, the weight being

so adjusted that when the pressure on the system reaches about 16½ pounds it is lifted, causing the valve to operate, which, in its action, relieves the pressure, allowing the increased bulk of the water to enter the expansion tank.

The opposite end of the valve opens toward the heating system; and as this is not equipped with a weight, the water in the tank flows down into the heating system unchecked as soon as the pressure on the valve is removed, this action keeping the system full of water and free from the formation of a vacuum. The pressure of 16½ pounds represents a temperature in the water of about 250 degrees.

The Honeywell generator and the Pierce heat-economizer are

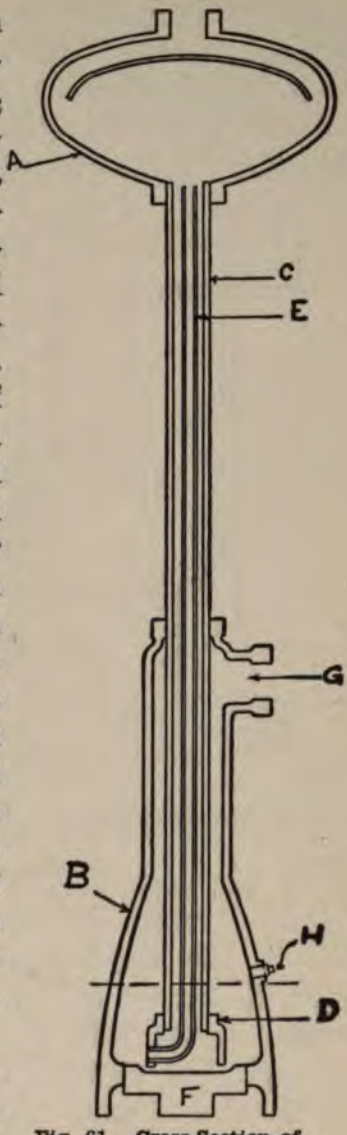


Fig. 61. Cross-Section of Honeywell Generator.

mercury appliances somewhat similar to each other in construction and operation. Fig. 61 is a cross-section of a **Honeywell generator.** At the top is the elliptical-shaped casting A, which is connected to the bottle-shaped casting

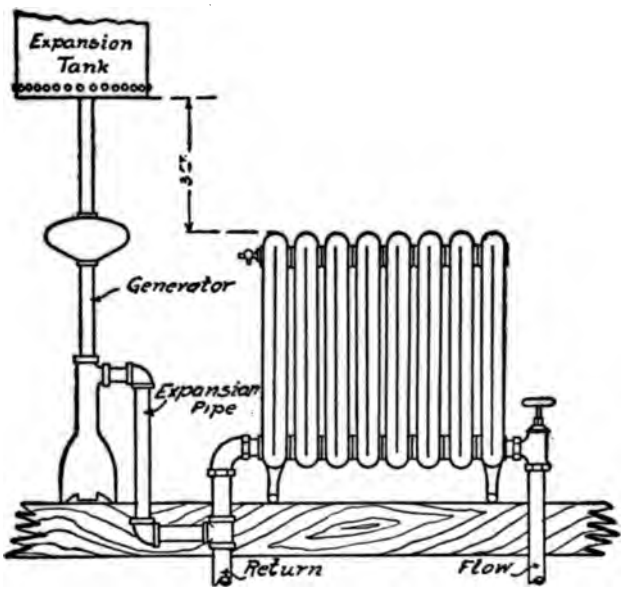


Fig. 62. Honeywell Generator Located Directly under Expansion Tank.

B by the pipe C. This pipe extends almost to the bottom of the generator, terminating in the cup-shaped shoe D. A smaller pipe E, curved at the bottom to fit into an orifice in the side of the shoe D, passes up through the center of the pipe C, the two pipes being of equal height at the top. The plug F screws into the bottom of the casting B, making it entirely tight, except for the side

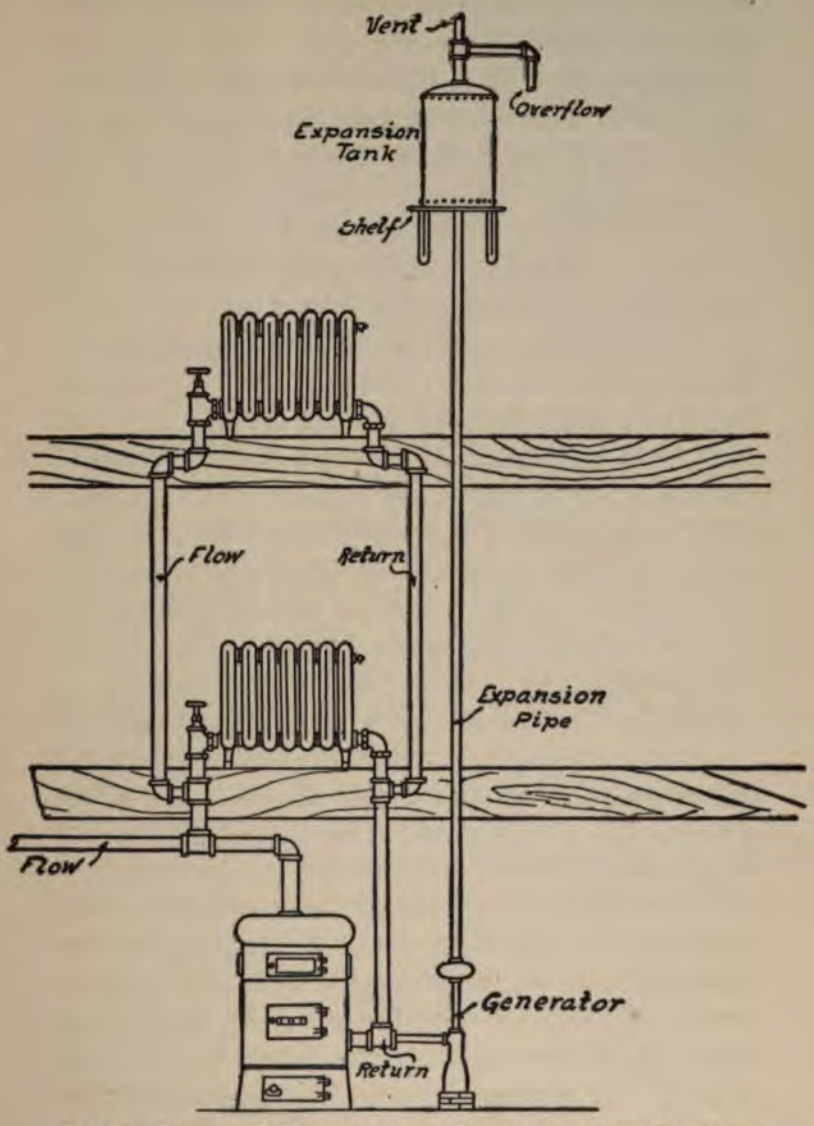


Fig. 63. Honeywell Generator Located in Basement and Connected with Return Pipe to Heater.

opening G, into which the expansion line from the heating system is connected. There is also a small opening at H which is sealed. The plug here can be removed, and the generator drained of all water, without disturbing the mercury which fills the bottom of the casting B to the depth of about 1½ inches. The dash line shows the height of mercury when the water is cold and there is no fire in the heater.

The generator may be located directly under the expansion tank, as illustrated in Fig. 62, or it may be placed in the basement near the rear of the heater, and from here connected with the return pipe, as shown in Fig. 63. Of the two, this latter position is the one preferred. In the event of such location, the expansion pipe is connected from the top of the generator, whence it rises to the ceiling of the basement, and is carried along until a point is reached where it is convenient to rise to the expansion tank.

The operation of the generator on a heating system can be described as follows: Almost as soon as the fire is started, the water in the system begins to expand, the expansion through the opening G (Fig. 61) pressing down on the mercury in the bottom of the generator. As the power of the expansion continues to increase, the supply of mercury is forced up the standpipe C and the small circulating pipe E. The mercury in the bottom of the generator is lowered to the top side of the inlet in the shoe of the circulating pipe E. At this point the mer-

cury will have reached the top of both the outer standpipe and the circulating tube; and the water, having forced it below the opening of the circulating pipe E, will itself enter and pass through this pipe, carrying a quantity of mercury with it. When the water and mercury reach the top of this pipe, the water will pass around the diaphragm or deflector in the top of the casting A, and out through the expansion tank; while the mercury, owing to its density being far greater than that of the water, will separate itself at the top of pipe E, and return to the bottom of the generator through pipe C, maintaining a constant circulation through the generator, in this manner acting quite similarly to a balanced valve.

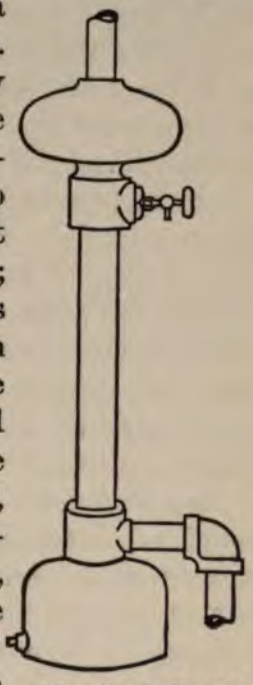


Fig. 64. "Pierce" Heat-Economizer.

The amount of mercury in the generator is sufficient to hold the pressure to about 10 pounds, or to a temperature of 240° F., without permitting a boiling of the water in the system. The deflector or baffle-plate in the top of casting A prevents loss of mercury when the apparatus is filled from city pressure, or in case a boiling of the water arises in the system.

The **Pierce heat-economizer**, Fig. 64, is not unlike the Honeywell generator. The principle involved in its construction—two pipes, one within the other, the outer pipe connecting the top casting (which is provided with deflectors cast on the inside), with the lower casting holding the mercury—is quite the same as that found in the similar appliance already described.

Many are the advantages derived from the use of any one of these appliances. Owing to the increase in the range of temperature it affords (up to 240°), the amount of radiating surface required should be about ten per cent less than that needed in the regular gravity system, and, where other surrounding conditions are favorable, it may be reduced fifteen or twenty per cent.

The increased pressure generated more than doubles the velocity of the circulation. Its usage permits of smaller-sized supply and return pipes and of reduced radiator tappings, consequently allowing of the use of smaller valves and fittings, and substantially reducing the cost of materials as well as the labor of installation.

The attachment of an accelerating appliance eliminates practically fifteen per cent of the water from the system, causing it to respond more quickly; and moreover, its use saves a proportionately large amount of fuel. A large proportion of hot-water work to-day is erected according to such plans.

Piping for Accelerated Systems. Installa-

tions of accelerated systems call for radical changes in the method of making pipe connections. Owing to the small sizes of the piping,

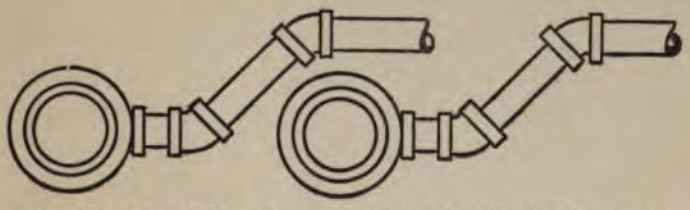


Fig. 65. Branch Pipe Connections for Accelerated Systems.

it is advisable to take all branches from the side of the main and to have them enter the side of the return, as shown in Fig. 65. The hot water will then flow to the end of each line before entering the branches, for, as previously stated, the heated portion of the water always hugs the

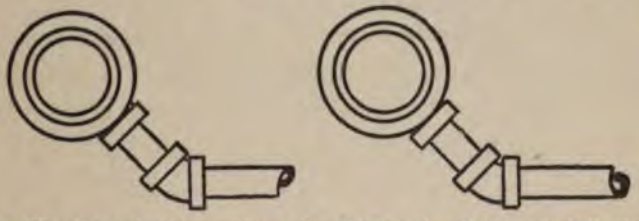


Fig. 66. Branch Connections for Piping in Accelerated Systems Running Directly to Upper Floors.

top of the main and each branch will receive its proper supply of hot water at about the same time. There are some modifications of this method, however. For example, when a branch near the heater feeds a riser to the upper floors without supplying a first-floor radiator, it is sometimes advisable to make the connection to the branch from the bottom of the main, as

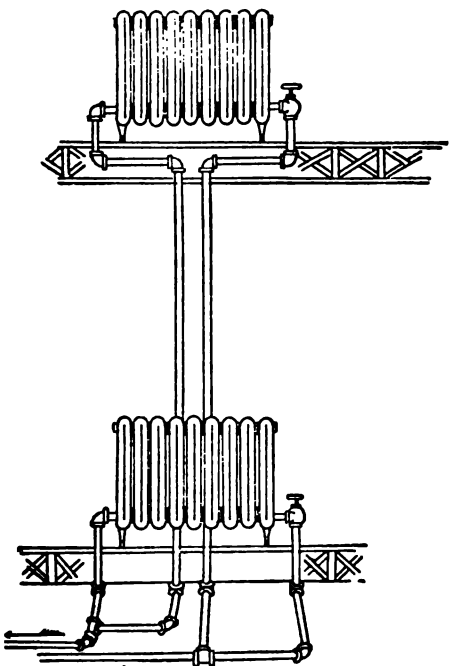


Fig. 67.

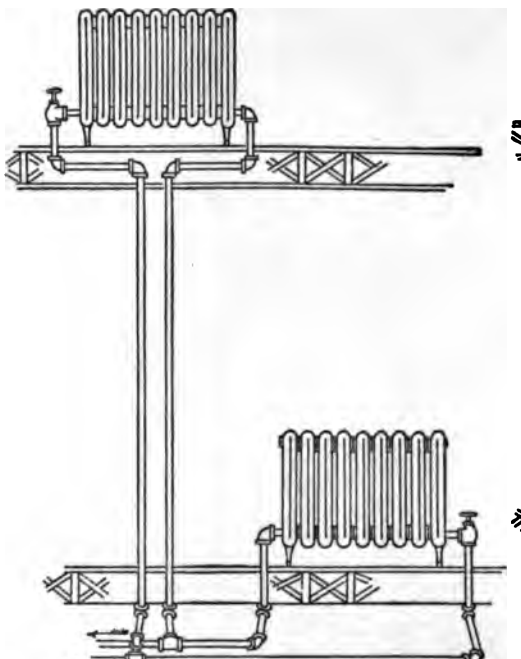


Fig. 68.

Methods of Taking Off Risers on Ends of Mains.

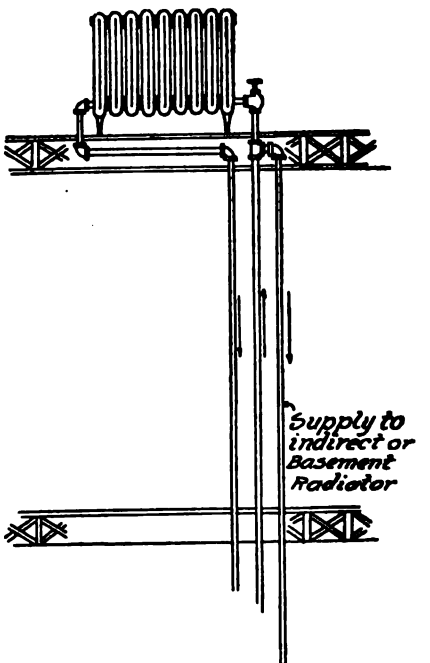
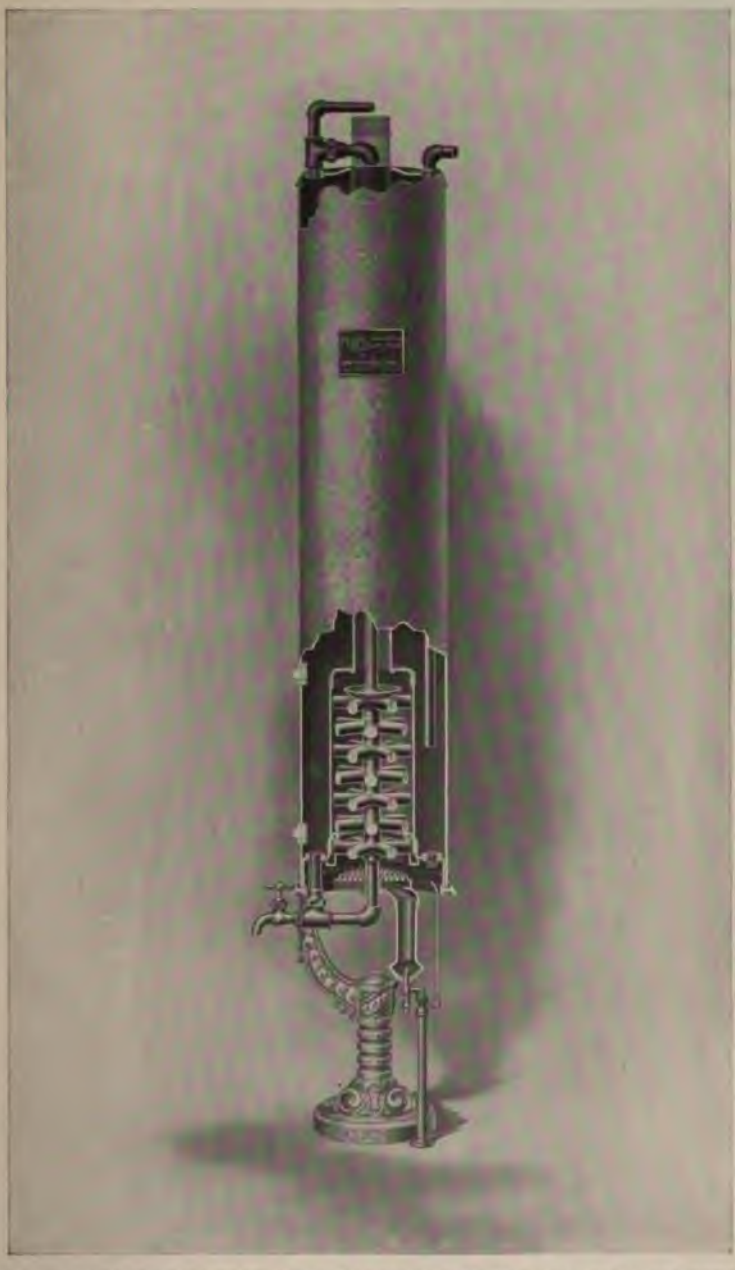


Fig. 69. How to Pipe to Secure Good Circulation in Basement Radiators.



"ELECTRIC-WELD" SINGLE-COMBINATION HEATER AND BOILER.

shown in Fig. 66. No riser should be taken from the end of a main, if such a connection can possibly be avoided. Take the connection to first-floor radiator from the end of a main, and the branch to riser from the side of this connection. Figs. 67 and 68 show two methods of accomplishing this, either one of which may be followed with success. In feeding basement radiators of either the direct or indirect pattern (described later), the supply should be taken from a riser at some point above the ceiling of the first floor; and the radiators should be fed from overhead by this drop pipe, as illustrated in Fig. 69.

For accelerated systems the radiator tappings are much smaller than with the usual installations. Table VI, showing the difference, will serve as a guide.

TABLE VI

Radiator Tappings for Accelerated Systems of Hot-Water Heating

FIRST FLOOR

Size of Radiator	Tapping
Up to 25 sq. ft.	½-inch
25 to 60 " "	¾ "
Over 60 " "	1 "

SECOND FLOOR

Up to 30 sq. ft.	½-inch
30 to 100 " "	¾ "
Over 100 " "	1 "

THIRD FLOOR

Up to 50 sq. ft.	½-inch
50 to 125 " "	¾ "
Over 125 " "	1 "

Although the radiation, with the accelerated system, may properly be reduced ten per cent,

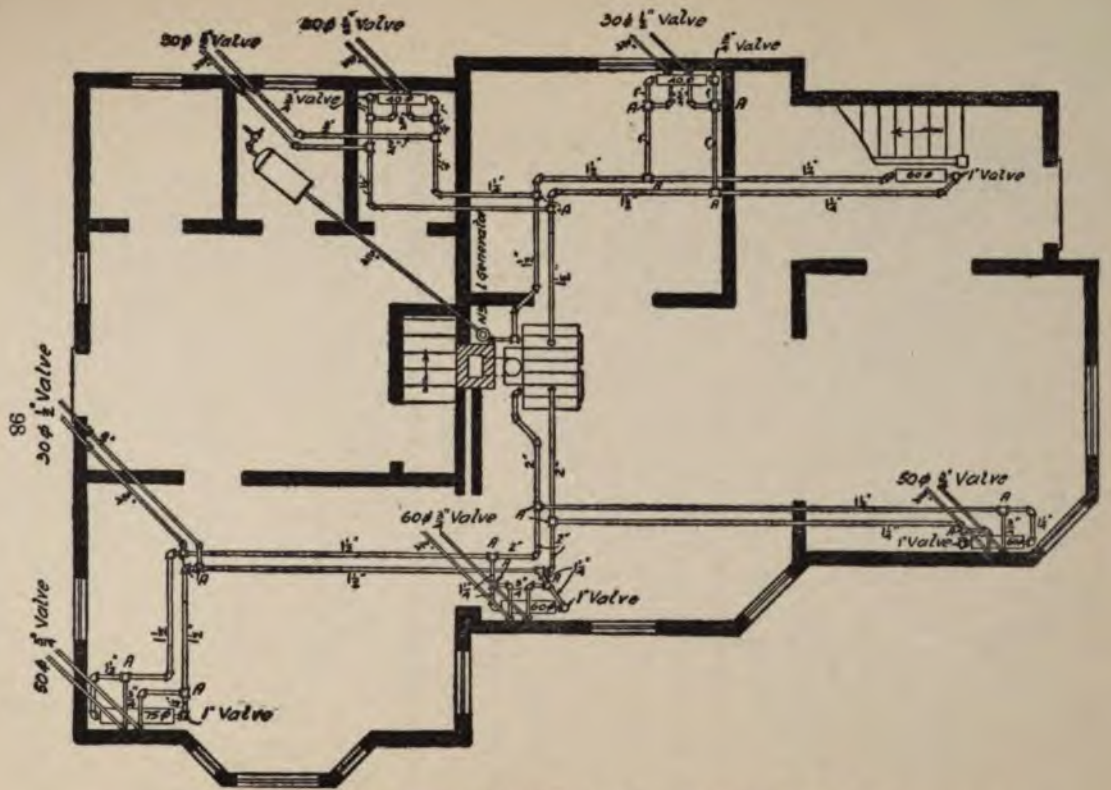


Fig. 70. Plan of Small Accelerated Job of Thirteen Radiators.
Piping shown on first-floor plan; oblique lines denote risers to second-floor radiators.

the heater installed should be of the same size as that required if placed on an open gravity system. It is considered good practice in connection with an accelerated system, to figure on the use of a heater having a rating fifty per cent larger than the actual square feet in cast-iron radiation on the job, making the usual allowance for indirect or direct-indirect radiation.

The mains should have an area of approximately 100 square inches for each 100 square feet in direct radiators supplied, and all branches should be of the same size pipe as the risers which they feed, with the exception that when a branch of extended length is taken from near the end of an extremely long main, the branch should be one size larger than the riser. Table VII gives the sizes of mains required to supply varying amounts of radiating surface under the accelerated system.

TABLE VII
Sizes of Mains for Accelerated Hot-Water Heating

Size of Main	Square Feet of Radiation Supplied
1¼ inch	100 to 150
1½ "	150 to 200
2 "	200 to 400
2½ "	400 to 600
3 "	600 to 1,000
3½ "	1,000 to 1,400
4 "	1,400 to 2,000

Fig. 70 shows a plan of a small accelerated job of thirteen radiators, with the sizes of flow and return mains, branches, radiators, and valves marked. For convenience in illustrating, the piping is shown on the first-floor plan.

The oblique lines denote risers to second-floor radiators.

The success attained by the use of these several original methods of accelerated hot-water

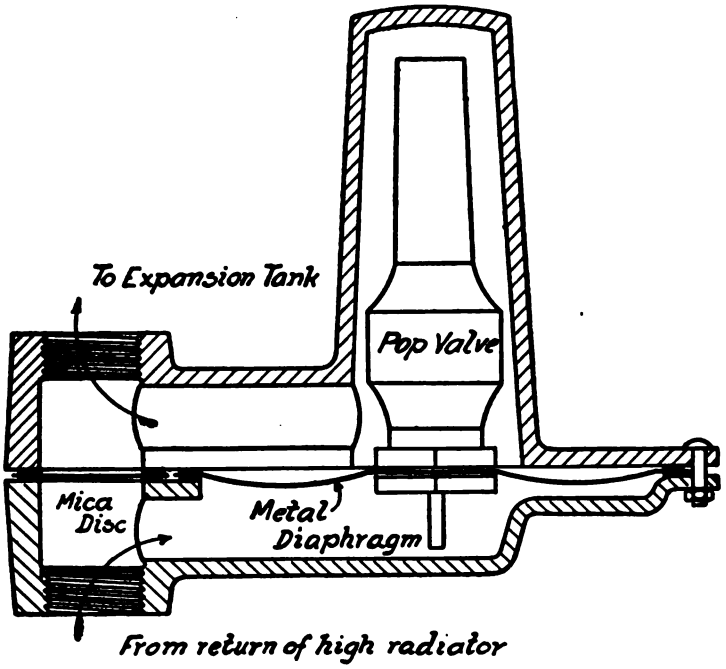


Fig. 71. Section of Hydro-Vacuum Circulator.

heating has led to the placing upon the market of several new appliances, all aiming to "assist" the circulation in the apparatus. One such device called the **Hydro-vacuum Circulator** consists of a pop safety-valve enclosed within a housing, the attachment being placed upon the expansion pipe. Fig. 71 is a sectional view of the appliance, showing the pop valve referred

to, the seat of which is held in position by a metal diaphragm, very thin and as resilient as a rubber cushion. The contraction of the water in cooling produces a pull (created by vacuum)

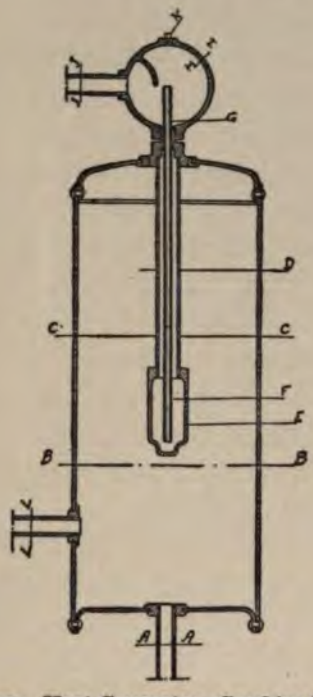


Fig. 72. Milwaukee Heat-Generator Combined with Expansion Tank.

on the under side of the diaphragm, which force, together with the weight of water in the expansion tank and in the pipe above, opens the valve by depressing the seat, thereby allowing the water in the tank to enter the heating system. As a safeguard against a possible sticking of the valve, the straightway passage through the cir-

culator is closed, as shown in the illustration, by a disc of amber mica which will break under a pressure of about twenty pounds. This provision thereby makes it impossible to accumulate a dangerous pressure on the system.

Another device for accelerating circulation by pressure is the **Milwaukee Heat-Generator**, a mercury appliance contained within the expansion tank, as illustrated in Fig. 72. A mercury-pot is held suspended within the center of the tank, by a pipe which screws into an opening at the top end of the tank; and a round separating chamber is screwed on the top end of this tank. A small circulating pipe is contained within the larger one, the lower end being submerged in the mercury, from which it extends upward through the top opening of the tank into the separating chamber. The outer casing of pipe is provided with two holes at C C.

The tank is filled to about one-quarter its capacity; and the water, expanding when heated, forms an air cushion at the top of the tank. The pressure entering the outer casing or pipe through the openings C C presses down upon the mercury, forcing it up to the circulating tube. When the mercury reaches the point marked G at the bottom of the separating chamber, there should be about ten pounds pressure on the system; and a further increase in temperature will cause the mercury to spill over or discharge at the top of the circulating pipe into the separating chamber, this action relieving the

pressure on the system. The mercury which in this manner finds its way into the separating chamber, then re-enters the circulating tube through the small opening provided at G, and drops to the mercury-pot.

In Fig. 72, A A is the expansion pipe; B, the normal height of water in the tank; C C, the openings in the outer tube or casing marked D; E, the mercury pot; F, the circulating tube; G, the opening in tube F at the bottom of the separating chamber H; J J, the overflow and vent pipe; K, a plugged opening for admitting the mercury to the device.

There are other devices of a similar nature for accelerating hot-water circulation; but the descriptions of those already mentioned will give the reader an idea of the general construction and operation of practically all other types.

RADIATING SURFACES

Radiating surfaces are to be had in a multitude of shapes and designs adapted to any desired space or location. They are manufactured of cast iron, wrought iron, and steel, and are produced either in the form of the ordinary type of column radiator or as pipe coils.

In heating systems, both steam and hot-water, there are three varieties of radiation—namely, **Direct, Direct-Indirect,** and **Indirect.**

Direct Radiators are located directly in the room or apartment to be heated. They are of the type illustrated in Fig. 73. This form of

radiator and the pipe coils formerly installed for radiating purposes were unsightly, cumbersome objects; but as now manufactured in a variety of beautiful designs, direct radiators are

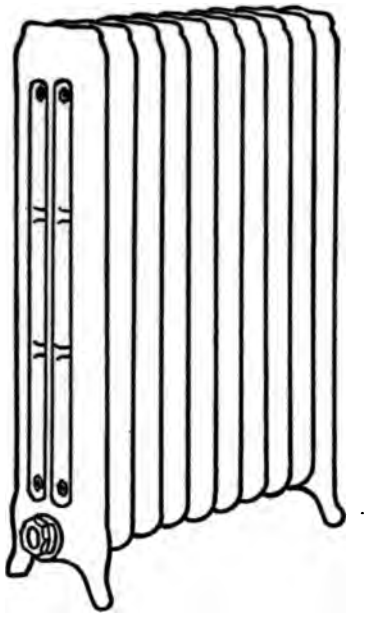


Fig. 73. Common Form of Direct Radiator for Steam or Hot Water.

an ornament to the room in which they are placed. Pipe coils at the present time are employed only in the heating of factories or buildings of similar nature.

Direct-indirect radiators are placed in the same manner as direct radiators, but also arranged with a box-base fitting under the lower part tightly. This box-base is provided with a damper; and an iron duct, connecting with an

aperture in the wall, conveys the air from outside the building, admitting the supply to the boxing below the radiator, from which it is

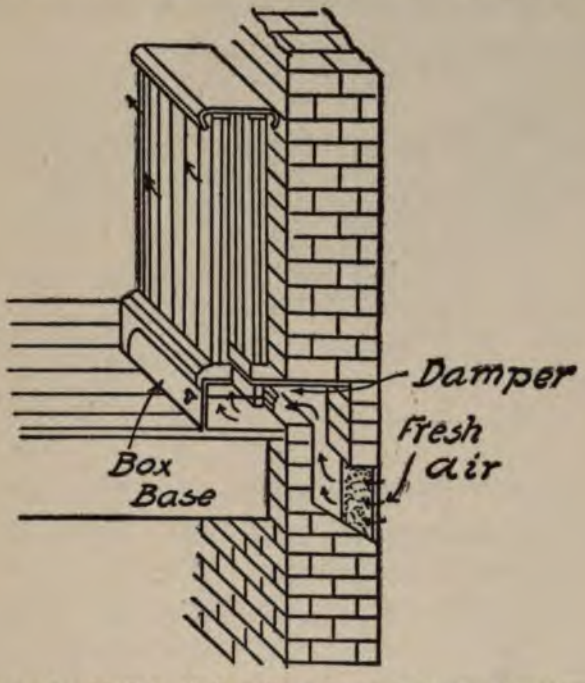


Fig. 74. Method of Installing Direct-Indirect Radiators.

warmed by passing over the heated surface of the radiator. Fig. 74 illustrates this type of radiation, which is largely used in buildings where it is necessary to provide specially for the admission of fresh air to assist in ventilation.

Indirect radiators are located outside the room, usually within a casing or bricked-in chamber in the basement. The pure cold air from without the building is introduced or car-

ried to the radiator through a pipe styled a **cold-air duct,** the supply, after passing over and between the surfaces of the radiator, being carried through another pipe connection styled a **warm-**

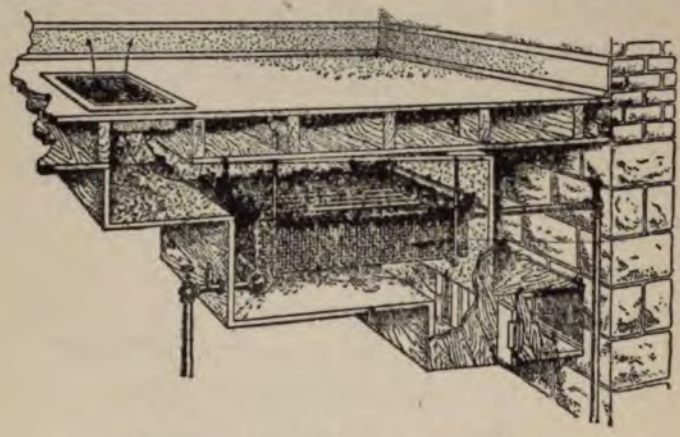


Fig. 75. Method of Installing Indirect Radiators.

air duct to a register situated in the floor or wall of the room to be heated.

Fig. 75 illustrates the method of "indirect" heating. Several radiator sections are screwed or nippled together, and, when assembled, form a so-called **stack** of indirect radiation. Care must be exercised in boxing or casing such a stack, as it is necessary that the box or casing fit snugly against the stack in order to insure a passage of the cold air through the radiator and prevent a circulation around it.

The cold-air duct should be provided with a suitable damper in order that the cold-air supply may be controlled. It is customary to admit

the outside air at and below one end of the casing, taking the warm or heated supply from the top at the opposite end.

The early methods of bricking a chamber for the use of indirects have been discarded in favor of portable boxing, which may be constructed of matched boards lined with tin, or, better still, may consist of a casing made of galvanized iron. The casing should be of such depth that a space of at least eight inches will exist between it and the lower side of the stack, and a space of ten or twelve inches between the top of the stack and the upper wall of the casing. The stack is usually supported on bars of iron or short lengths of ¾-inch or 1-inch pipe suspended from the ceiling by hangers.

Table VIII indicates the proper sizes of registers and air ducts for indirect work.

Pipe coils, while largely used as radiation for factory and greenhouse heating, are seldom employed in house-heating work, by reason of the large amount of wall space they occupy. Quite frequently, in the early days of steam heating, it was the practice to assemble a mass of pipe coils and box them in on the sides and ends by cast-iron open-work or latticed panels, with a top either of cast iron or marble. This construction was known as a **box coil**—a type of coil now seldom if ever used, because of its cumbersome appearance as well as its inefficiency.

Coils of present-day use, while found in several forms, are of two general varieties—namely,

TABLE VIII

Sizes of Cold- and Hot-Air Ducts and Registers for Indirect Heating

(For First Floor)

Square Feet of Heating Surface	Square Inches Cold-Air Duct	Square Inches Hot-Air Duct	Size of Register
INDIRECT HOT WATER			
26	36	48	8x12 in.
52	54	72	9x12 "
78	72	96	10x14 "
104	96	120	12x15 "
130	108	144	12x19 "
156	126	168	14x22 "
182	144	192	14x24 "
208	162	216	16x20 "
234	180	240	16x24 "
260	198	264	20x20 "
286	216	288	20x24 "
312	234	312	20x24 "
INDIRECT STEAM			
13	36	48	8x12 "
26	54	72	9x12 "
39	72	96	10x14 "
52	90	120	12x15 "
65	108	144	12x19 "
78	126	168	14x22 "
91	144	192	14x24 "
104	162	216	20x20 "
117	180	240	20x24 "
130	198	264	20x24 "
143	216	288	24x24 "
156	234	312	24x24 "

those made **with return bends**, as illustrated in Fig. 76; and those made with branch tees, or

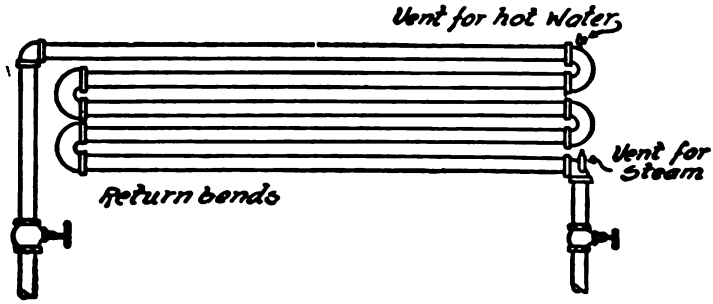


Fig. 76. Pipe-Coil Radiator with Return Bends—Flat or Wall Coil.

manifolds, as illustrated in Figs. 77 and 78. The **return-bend coil** of Fig. 76 is termed a **flat or wall coil**; that of Fig. 77, a **branch-tee miter coil**;

and that of Fig. 78, a **corner coil.** While there are other forms also to be found, those illustrated

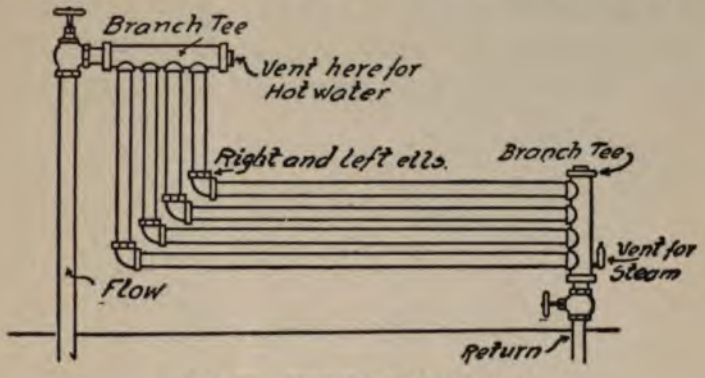


Fig. 77. Branch-Tee Miter Coil.

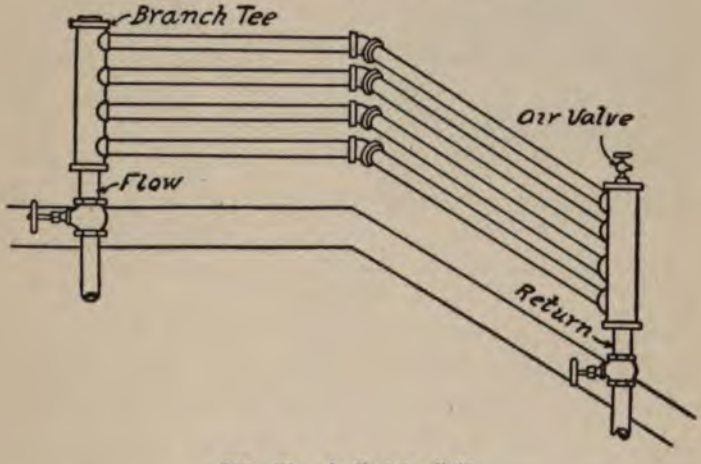
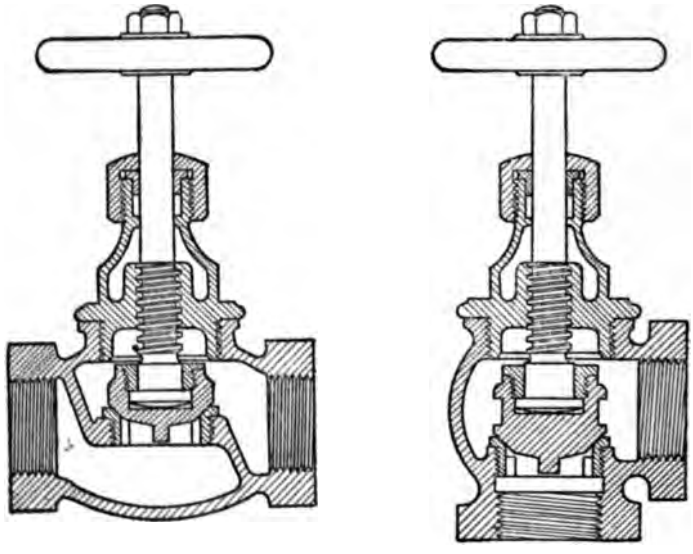


Fig. 78. A Corner Coil.

are the ones in common use. As it is customary to connect all coils on the two-pipe plan—that is, with a separate flow and return pipe—the constructions will do equally well for both steam and hot water.

VALVES

Kinds of Valves. Valves as used on steam or hot-water piping are of two principal varieties—namely, the **globe** or **angle** type, shown in Fig. 79; and the **gate valve**, shown in Fig. 80.



Globe Valve. Angle Valve.

Fig. 79. Types of Valves.

The former style is adapted for steam work, and, in its interior construction, has a valve-seat against which the disc is screwed when opening or closing the valve. By reason of the obstruction encountered in the interior mechanism of the globe valve, it is unwise to place is in a vertical position on a horizontal pipe; and, when necessary to use a valve of this character on a pipe run horizontally, it should be placed with its stem set horizontally or pitching slightly down-

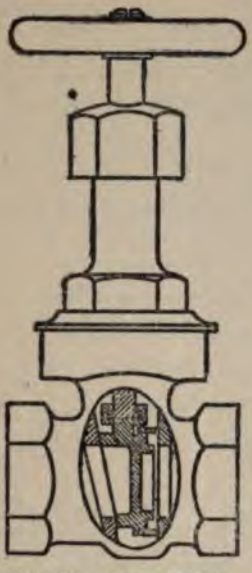


Fig. 80. Gate Valve.

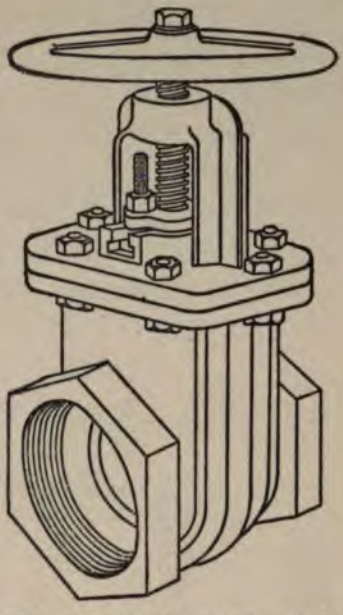


Fig. 82. Extra Large Gate Valve with Yoke or Saddle.

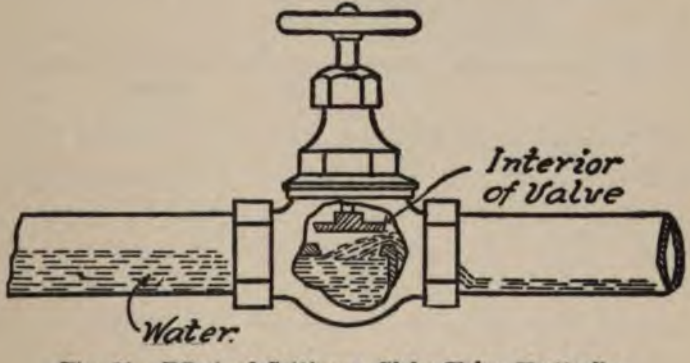


Fig. 81. Effect of Setting a Globe Valve Vertically.

ward. Fig. 81, showing the interior of a globe valve with the stem set vertically, illustrates clearly the difficulty arising from lodgment of the water of condensation.

With the gate valve for either steam or hot water, a free opening through the valve is se-

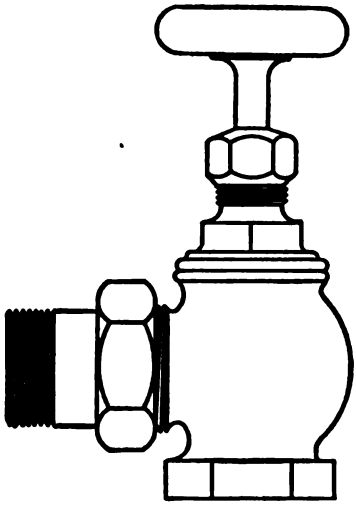


Fig. 83. Steam Radiator Valve.

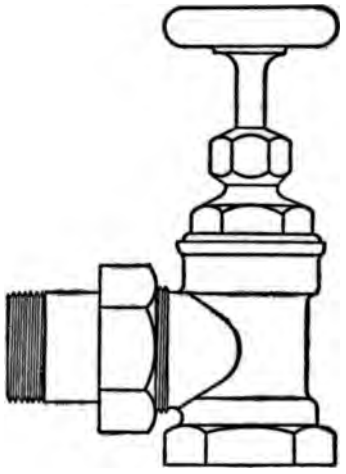


Fig. 84. Hot-Water Radiator Valve.

cured, as will be noticed from the interior view, Fig. 80. Small globe and gate valves are usually made of brass; and sizes above 2-inch or 2½-inch, ordinarily of iron, in some cases with brass trimmings. Extra large valves are constructed with a yoke or saddle, as illustrated in Fig. 82, which provision adds greater strength and insures ease of operation.

Radiator Valves. For use on radiators or units of heating surface, the universal types of

valves are the **steam radiator valve,** Fig. 83, and the **hot-water radiator valve,** Fig. 84. The former is of the angle type, and is usually provided with a union connection to facilitate joining with the radiator. The latter is also a form of angle valve, being termed a "quick-opening" valve from the fact that one-half turn of the stem either opens the port through the sleeve or closes it in like manner. This valve, too, is supplied with a union connection.

Radiator valves, steam and hot water, are produced in a great multiplicity of designs, all

Horizontal Check. Angle Check. Swing Check.

Fig. 85. Common Forms of Check-Valves.

of them, however, being intended to accomplish the purposes above set forth.

Check-Valves. When it is necessary that the supply of steam or water should flow always in one direction only, a form of valve known as a **check-valve** is placed on the piping in order to prevent any reverse circulation of the steam or water. Such appliances are manufactured in a variety of designs, the most common forms of which are illustrated in Fig. 85.

Air-Valves. It is essential to free all parts of the heating system, including the various

units of radiation, of the air which constantly accumulates in the upper portions of all surfaces of hot-water radiators, or which pockets in the piping owing to the fact that it is lighter than the water in circulation. In steam radiators or pipes, the air will settle toward the bottom of such surfaces, inasmuch as the accumulation is heavier than the supply of steam.

There are numberless forms of valves manufactured for the purpose of releasing air from heating systems. Some are styled **positive**, requiring the operation by hand of a wheel, or of a stem with a key, in order to open or close the valve. Others are **automatic** in their operation, opening by contraction when cold or when the steam is removed from contact with them, and closing by expansion when the supply again reaches the valve.

HEATING ACCESSORIES

A detailed description of all the various types of accessories or minor appliances used on heating work would require more space than is here available, and we shall therefore illustrate and describe only those which are necessary to the completion and to the perfect working of the ordinary steam or hot-water heating apparatus.

Steam Boiler Trimmings. There are certain appliances which should always be placed on a boiler used for heating purposes. One of the most important of these is the **water column**

and gauge, Fig. 86, for registering the height of water in the boiler. As a further safeguard in this respect, **try-cocks** or **gauge-cocks** are placed on this water column in order to prove the

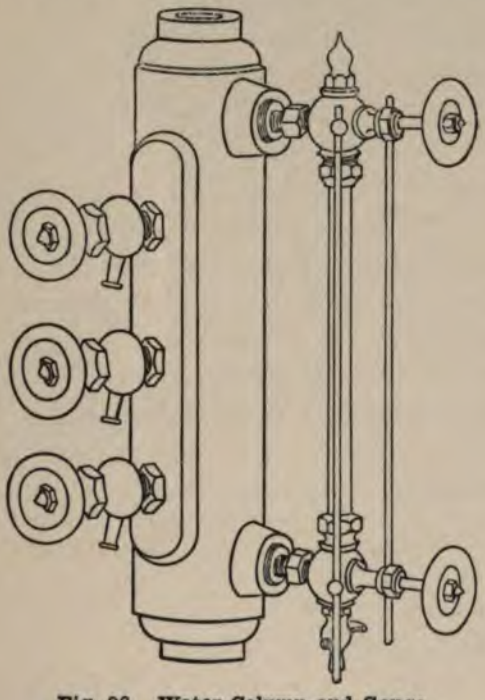


Fig. 86. Water Column and Gauge.

height of water should the glass from any cause be broken.

A steam gauge, Fig. 87, should be attached to every steam boiler. The gauges used are ordinarily of the Bourdon type, and consist of a hollow tube bent into circular form. One end is attached to an opening in the bottom of the gauge to which the steam supply is connected.

The free end of the tube is attached by gearing to a pin operating the hand or pointer, which moves across the dial shown on the face of the

Fig. 87. Steam Gauge.

gauge as the pressure on the interior tube straightens it, by this action indicating the pressure carried in pounds.

A steam boiler should invariably be fitted with an **automatic damper-regulator,** which

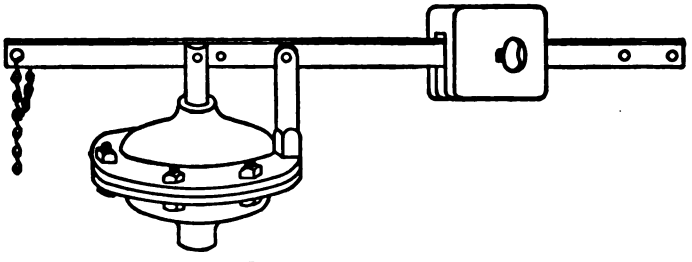


Fig. 88. Common Form of Automatic Damper-Regulator.

opens or closes its draught doors according to the pressure of steam on the boiler. This attachment may be so set as to cause the draught door to remain closed and the check door open, or so that a certain pressure of steam will operate both doors automatically. In the construction of this regulator, usually two castings in form

resembling an old-fashioned soup plate are bolted together, with a rubber diaphragm between. The pot thus formed is connected to the boiler in such a manner that the diaphragm receives the pressure of steam against its lower side, raising its center against a plun-

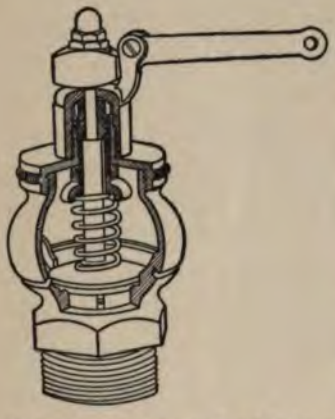


Fig. 89. Spring or Pop Safety-Valve.

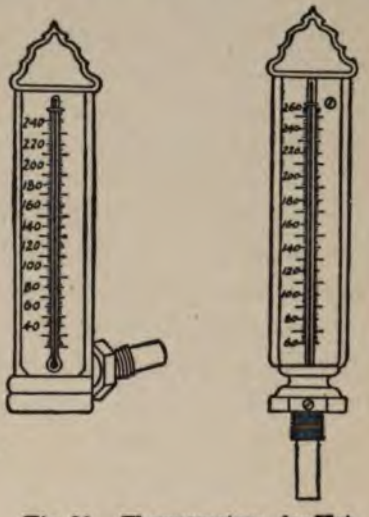


Fig. 90. Thermometers for Hot-Water Heaters.
Angle type at left; straight type at right.

ger inserted through an opening in the top casting or half of the pot. A rod bolted to this plunger is also attached to a lip on the outer edge of the upper casting, thereby forming a lever which operates the draught and check doors by chains connected to them from the ends of the rod. A sliding weight placed on this lever rod may be moved to regulate the pressure at which the device will operate. Fig. 88 shows

the common form of this automatic damper-regulator.

As a matter of safety, and to provide against possible danger or damage to the boiler from the generation of an excessive pressure, all steam boilers should be fitted with a proper **safety-valve.** Such valves are all practically built on the same principle, consisting of a valve seated in such a manner as to open outward, the disc being held in place by a weight or spring. There are three varieties in common use—the **lever** safety-valve; the **spring** or **pop** safety-valve; and the **weighted** valve, the latter consisting usually of an ordinary style of valve with disc and seat, the disc being held in place against the pressure of steam by a ball weight mounted on top of the stem, the balls provided being of various weights according to the pressure it is desired to carry. The spring "pop" valve, Fig. 89, is the type used on low-pressure heating boilers to a greater extent than any other variety.

Each of the three types of safety-valve performs the same function. When the pressure of steam on the apparatus increases beyond the point at which the weight or spring of the valve will overcome its force, the disc is automatically raised from the valve-seat, and the excess of steam is thereby allowed to escape to the atmosphere, after which the weight or spring again closes the valve.

Hot-water heaters are provided with a

special form of **thermometer,** as shown in Fig. 90, for indicating the temperature of the water in the heating system, and also with an altitude

Fig. 91. Altitude Gauge for Hot-Water Heating System.

gauge, Fig. 91, which indicates at the heater the height of the water in the sytem.

THE CHIMNEY FLUE

In the construction of a building, there is one feature or part of it the efficiency of which is frequently overlooked or given but scant attention. We refer to the chimney flue. The perfect working of any one of the various types of modern heating apparatus depends largely upon the character of the chimney to which it is attached; and it is probable that ninety per cent of the failures of such apparatus to heat properly (when a heater of sufficient size and the proper amount of radiating surface are provided) are directly traceable to the chimney. A knowledge of the essential features to be considered in chimney building is therefore of the utmost importance.

Aside from the outlet at the top, the chim-

ney used with any heating apparatus should have no opening except that required to connect the smoke-pipe of the heater. This opening should conform in size to the smoke connection on the heater. All manufacturers of furnaces, steam boilers, and hot-water heaters are careful to indicate the size of smoke connection best

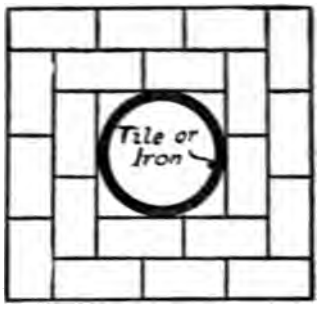


Fig. 92. Brick Flue with Round Tile or Iron Lining.

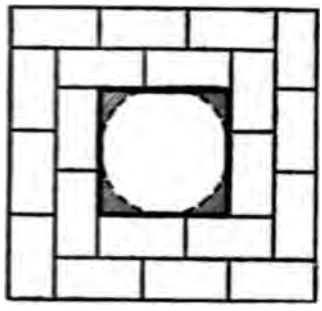


Fig. 93. Square Flue.

adapted to the use of a certain size of heater, and this specified size should never be reduced.

The flue should start but a few inches below the smoke-pipe opening, the part of the chimney beneath being constructed solid up to this point. Smoke in ascending a flue travels in a spiral form against the pressure of the atmosphere, and will not rise until the air in the flue is sufficiently lightened by expansion to overcome this pressure, when it will be forced upward by the circulation caused by opening a draught door below the grate of the heater.

Flues are built **round**, **square**, and **oblong**; and the degree of efficiency of the three different styles is indicated in the order named. A brick

flue with a round tile or iron lining, as illustrated in Fig. 92, is, without doubt, the best that can be procured, as the heated gases and smoke occupy its full area. The next best type is the square flue, illustrated in Fig. 93. The dotted line indicates the area of the flue reserved by the smoke and gases, the shaded portion denot-

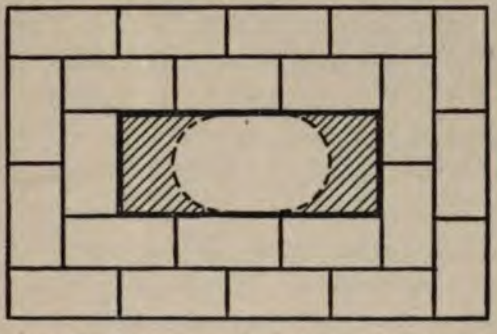


Fig. 94. Oblong Flue, Showing Large Proportion of Useless Space.

ing the dead air space. The illustration of the oblong flue, Fig. 94, shows these features also, and the reader will note the increased proportion of useless air space in this type. This condition may be carried to such an extreme—as, for instance, with a flue 4 by 16 inches—that the amount of dead air space will equal or even exceed that portion of the flue which is active surface, with the result that a down draught is produced, causing friction by mingling with the opposing current of air, and rendering the flue practically useless. A clear opening of an 8 by 8-inch flue, with an area of 64 square inches, would be far better and more efficient than a

flue with an opening 4 by 24 inches, although the latter would have an area of 96 square inches, or a capacity more than one-third greater.

A chimney erected through the center of a building is more efficient than one built in an outside wall, because it is surrounded by heated or warm rooms which in a large measure prevent the condensation of the smoke, the cooling of the gases, and the precipitation of soot. When constructed in an outside wall, the side of the chimney flue exposed to the air should be at least eight inches in thickness. In an outside chimney, the condensation of the smoke and gases from certain grades of coal will frequently cause the sulphur and creosote ingredients to run down the chimney into the smoke-pipe, by this action causing its rapid destruction. These products of combustion leave a dry deposit, which hardens to the consistency of iron, clogging the dampers in the smoke-pipe or in the smoke-hood of the heater.

Offsetting of chimney flues should, if possible, invariably be avoided. If conditions, however, make such a construction absolutely necessary, the angle of the offset should be as sharp as possible; otherwise the soot and ashes will form a deposit in the offset and clog up the flue. Fig. 95 illustrates this, and shows by dotted line how offset should have been made.

Height in a flue simply governs velocity, having no effect whatever on the area, which

should be sufficient for the work demanded of it. A chimney in a building of two or more stories has sufficient height to be suitable for all purposes. It should extend above the building to such a distance that adjacent structures

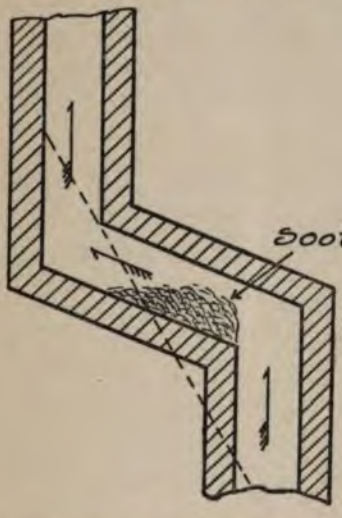


Fig. 95. Effect of Offsetting Flue at a Large Angle.

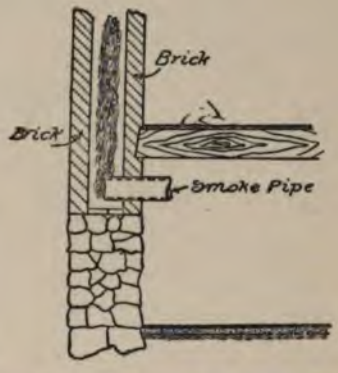


Fig. 96. A Common Cause of Poor Draught — Smoke-Pipe Extending Too Far into Flue Opening.

or roofs will not interfere with its working or cause a possible down draught by reason of the wind blowing over the roof and down through the chimney.

Trouble with draught on a heating system may be due to any one of the following causes:

1. Obstructions in flue, such as extensions of bricks or timbers, or an extension of smoke-pipe too far into flue opening, as shown in Fig. 96.

2. Loose or open clean-out doors at base of chimney.

3. Height insufficient to clear surrounding obstructions to draught.

4. Insufficient area for work demanded of flue.

5. An enlarged or contracted chimney at some point in its length. A flue is only as large as the area at its smallest portion.

6. Two or more smoke-pipes from different apparatus connected to same chimney, one working against another.

7. Offsets at too great an angle—that is, too flat.

8. Loose division walls between flues, one of which is used for the heater.

These are the causes of some of the difficulties commonly experienced with chimneys, and their enumeration should prove a valuable aid in locating any possible trouble. As a guide to follow in the proper construction of a chimney, Table IX is given, which shows the proper sizes of brick and tile flues for different-sized buildings. The dimensions of tile given are commercial sizes. The capacities scheduled have been found in practice to be entirely sufficient for ordinary work, and can be safely relied upon to render proper results.

TABLE IX

Sizes of Chimney Flues for Different-Sized Buildings

Capacity of Building	Brick	Tile, Square (Outside Dimensions)	Tile, Round (Inside Dimensions)
Up to 20,000 cu. ft.	8 x 12 in.	8½ x 13¼ in.	10 in.
20,000 to 40,000 " "	12 x 12 "	13 x 13 "	12 "
40,000 to 70,000 " "	12 x 16 "	13 x 18 "	15 "
70,000 to 100,000 " "	16 x 16 "	18 x 18 "	18 "
100,000 to 150,000 " "	16 x 24 "	.....	.....
150,000 to 250,000 " "	24 x 24 "	.....	.....

Square tile for flue linings are sized and listed commercially from outside dimensions; round tile, from inside dimensions.

VACUUM AND VAPOR HEATING

Properly to understand vacuum and vapor heating, it is necessary not only to have knowledge of the meaning and applications of these terms, but also to understand the reasons for the application of the principles to heating apparatus.

In all standard dictionaries a vacuum is defined as an "empty space." We speak of a bottle from which the contents have been removed as being empty, and, according to the dictionary definition, this condition would therefore seem to be a vacuum. This, however, is not true, for, while the visible contents have been extracted from the bottle, the space formerly occupied by these contents has simply been filled with another and invisible volume—the vaporous gas we call air. This supply of air is under a pressure of 14.7 pounds, the same as the outside atmosphere surrounding the bottle; and this force we call **atmospheric pressure.**

If an attempt is made to refill the bottle without providing a vent or opening for this inner air to escape, it will be found impossible to refill it.

What causes atmospheric pressure? The earth is surrounded by a belt of elastic gas many miles thick. This air, containing more or less moisture in the form of vapor of water, is denser nearer to the earth than at high altitudes. Like all other substances, air has weight,

because of the attraction of gravity. It exerts a pressure upon all objects upon the earth to the extent of 14.7 pounds per square inch at sea-level. In other words, the atmospheric pressure upon a surface is simply equivalent to the weight of the column of air pressing upon that surface. On account of air being a fluid, the pressure is exerted equally in all directions. The higher we ascend in the air, the less the degree of this pressure. Water in an open vessel will boil at sea-level when it has been heated to a temperature of 212° F.; at an altitude of about two miles above sea-level, the same supply of water will boil or vaporize at a temperature of approximately 190° F.

Now, returning again to the illustrations afforded by a consideration of the water- and air-filled bottle, let the air itself be extracted from the bottle. The bottle will then be, as we say, under a **vacuum**, and a vacuum exerts a pull upon the opening in the neck of the bottle.

What has the information gained from this discussion to do with the heating question? Let us see. Water, when vaporized or converted into the gaseous form we call "steam," occupies a space about 1,700 times as great as it did in its original liquid state; in other words, one cubic inch of water, when vaporized, will be productive of 1,700 cubic inches of steam. Fill a radiator with steam, and then condense the supply. It will occupy as water but one sixteen hundred and ninety-ninth part of the space it

occupied as steam, the remainder of the space being filled with air sucked into the radiator through the air-valve, and this volume of air has the pressure of the atmosphere. In circulating steam, it is necessary to overcome this pressure, and to drive the air from the radiator through the valve before the radiator can again be filled with steam. Air is the arch enemy of the heating contractor.

Vacuum heating provides a method for keeping all air out of a heating system, and, at the same time, for exerting a pull, by means of a pump or other device, upon the return ends of all units of radiation, thereby allowing and facilitating the flow of steam to all parts of the apparatus without pressure.

Vacuum Heating Systems. There are two classes of this kind of heating—first, those making use of a pump or other mechanical device for creating the vacuum; and second, non-mechanical systems which are used in connection with the ordinary methods of steam piping for residence work. Among the commercial systems in the former class may be named the **Webster,** the **Paul,** and the **Van Auken** systems; among those in the latter division are the **Trane,** the **K-M-C** (Morgan), the **Gorton,** the **Ryan,** the **Moline,** and the **Dunham.** All are designed to accomplish the same purpose—namely, that of circulating steam or vapor through a heating system at a

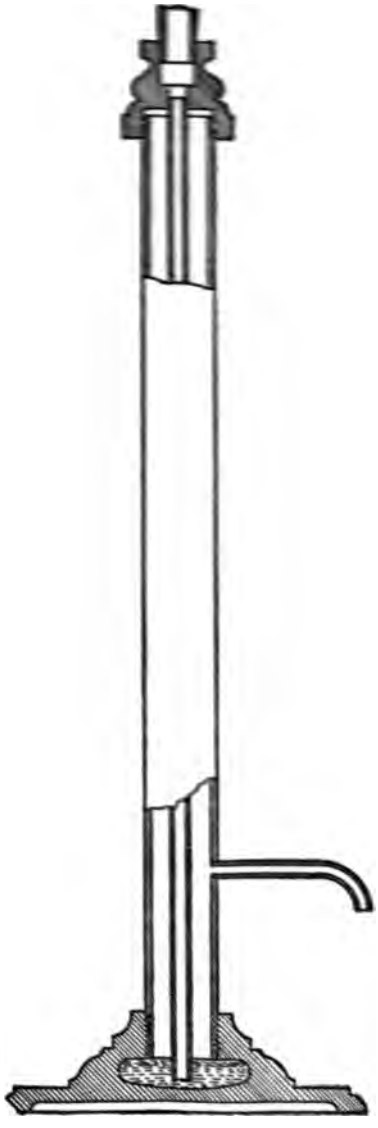


Fig. 97. Mercury Seal Appliance Used in Trane Vacuum Heating System.

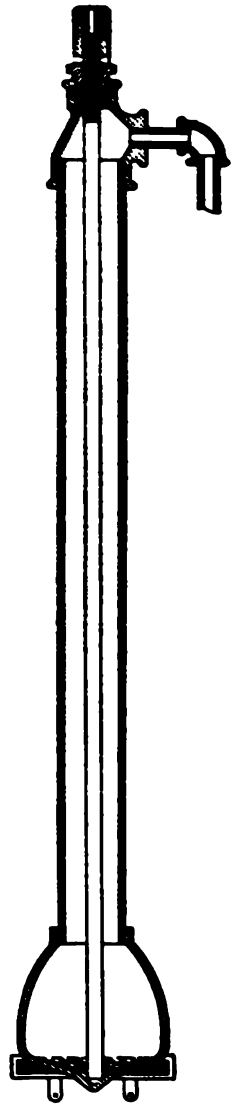


Fig. 98. Mercury Seal Appliance Used in K-M-C Vacuum Heating System.

MODERN KITCHEN IN A SMALL HOUSE.

pressure equal to or below that of the atmosphere.

The **Trane system** involves the use of a cup of mercury in the center of a device called a **mercury seal,** as illustrated by Fig. 97. A special form of automatic air-valve, having a union drip connection, is used on the return end

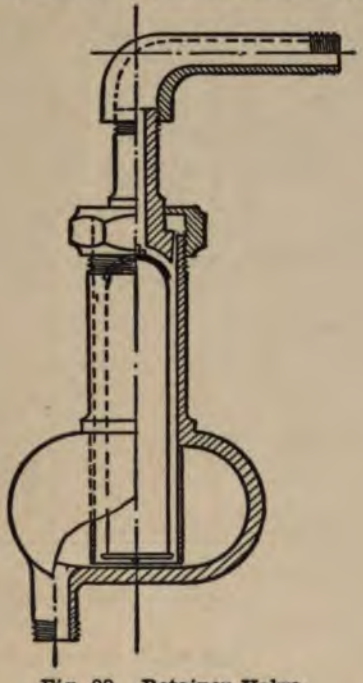


Fig. 99. Retainer Valve.

of each radiator. An air-pipe connecting to this valve is carried to the basement, where it is joined into a larger air-pipe called an **air-main.** This line follows closely the direction of the steam main, terminating at a point near to the boiler, where it drops down and connects to the

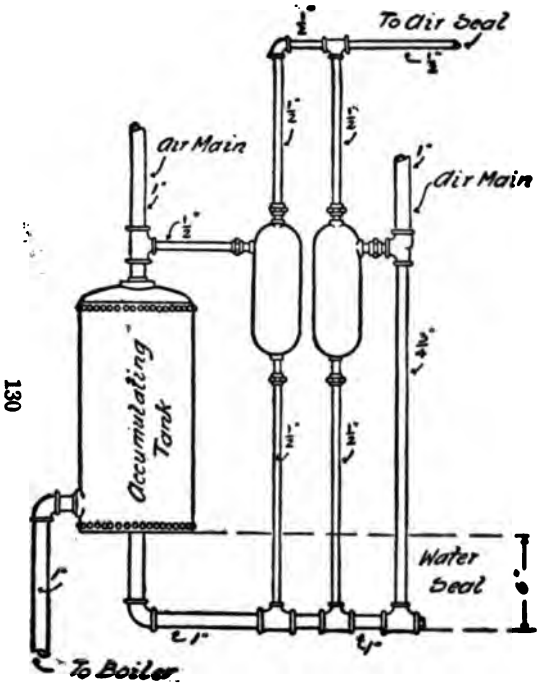


Fig. 100. Accumulating Tank Used in K-M-C System of Vacuum Heating.
Detail showing connection to floating check-valves when tank is set vertical.

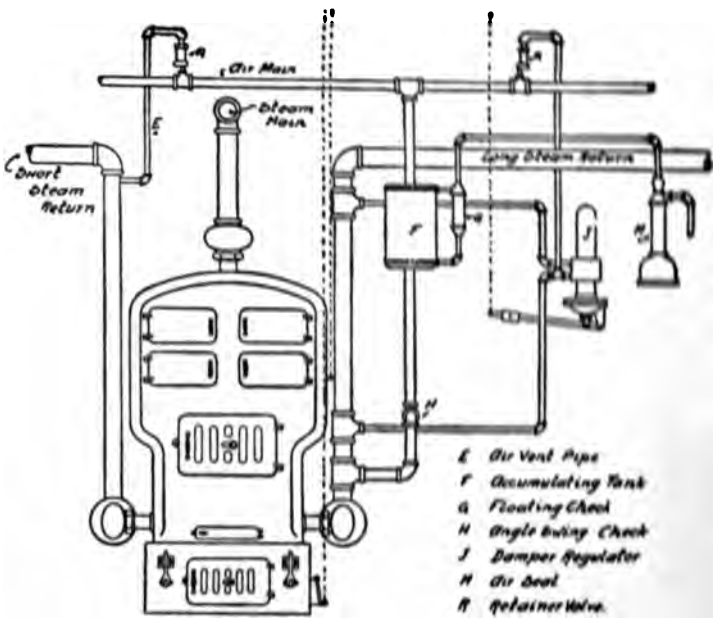


Fig. 101. Arrangement of Piping and Fixtures in K-M-C System of Vacuum Steam Heating.

top of the mercury-seal device. A slight pressure will force the air out of the seal through the mercury, which will, however, by reason of its greater density, effectively prevent the return of the air into the air-line, by this operation placing the system under a vacuum.

The **K-M-C system** also makes use of a mercury device, Fig. 98, in quite the same manner as the Trane. In connection with its usage, however, some special appliances are necessary. A small device, called a **retainer valve** (shown in Fig. 99), when placed on the return end of the radiator, is designed to prevent the steam from entering the air-line. Should any supply find its way into this air-pipe, it is taken to a small tank, called an **accumulating tank**, into which the air-line connects. As this tank is partially filled with water, it assists in condensing the steam; and from the accumulating tank, the air passes through floating check-valves before entering the mercury seal. Fig. 100 shows the method of connecting the tank, and also illustrates the floating check-valves; while Fig. 101 shows the arrangement of the piping and fixtures at the boiler.

The other systems of vapor and vacuum heating require the use of ejectors, air-traps, etc.

The **Gorton** arrangement is a vapor system involving heating below atmospheric pressure. In its application, the two-pipe method of piping

is employed. A **drainage valve**, Fig. 102, is used on the return end of each radiator, in operation being so sensitive that a very slight pressure will open it a sufficient distance to allow the air and the water of condensation to pass into the returns. Connected to the system in the basement, is an **automatic relief valve**, as shown in

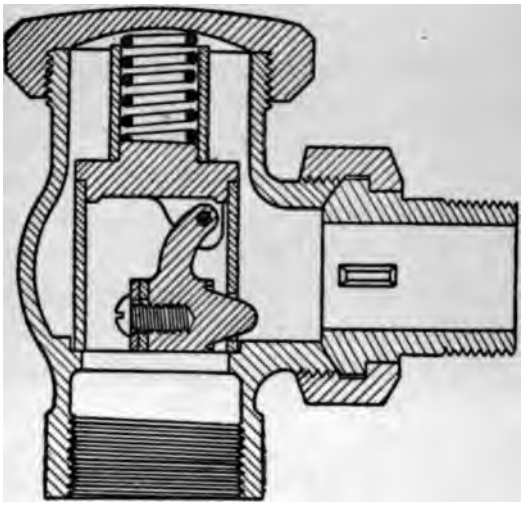


Fig. 102. Automatic Drainage Valve Used in Gorton System of Vacuum Steam Heating.

Fig. 103. This valve is operated by the difference in pressure between that of the steam and of the return pipes, remaining closed until the accumulation of air in the return mains increases the pressure, when it will open sufficiently to relieve the air, closing again after the release of the surplus. The arrangement of the connections at the boiler is shown in Fig. 104.

The **Ryan system** involves the use of air-

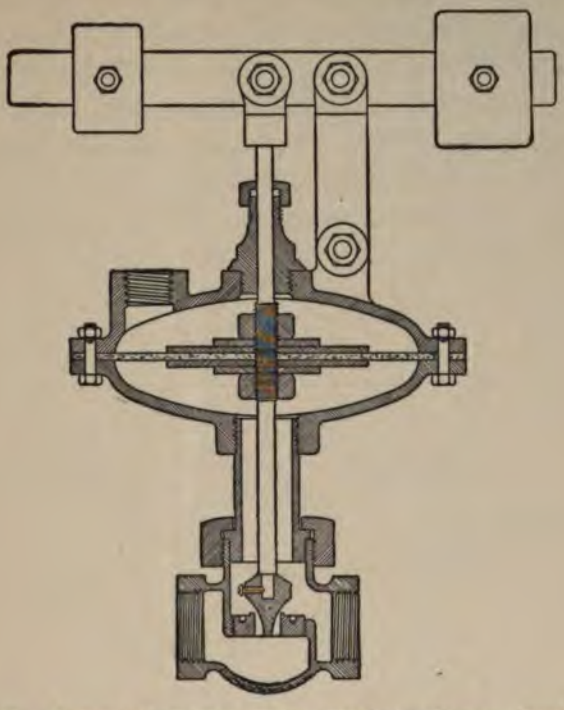


Fig. 103. Automatic Relief Valve Used in Gorton System of Vacuum Steam Heating.

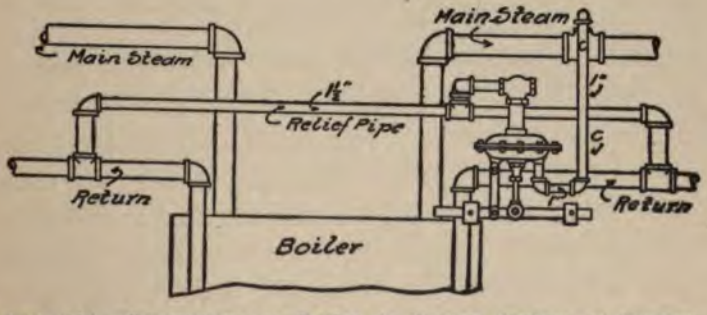


Fig. 104. Connections at Boiler in Gorton System of Vacuum Steam Heating.

lines similar to those of the K-M-C and Trane systems. With it the air is exhausted to the atmosphere through an air-trap. A small steam pipe connected directly to the trap from the boiler, acts as an exhauster in creating the vacuum pull upon the air-line.

The **Moline system** is styled the **Vacuo-Vapor Method,** and in the method of piping is

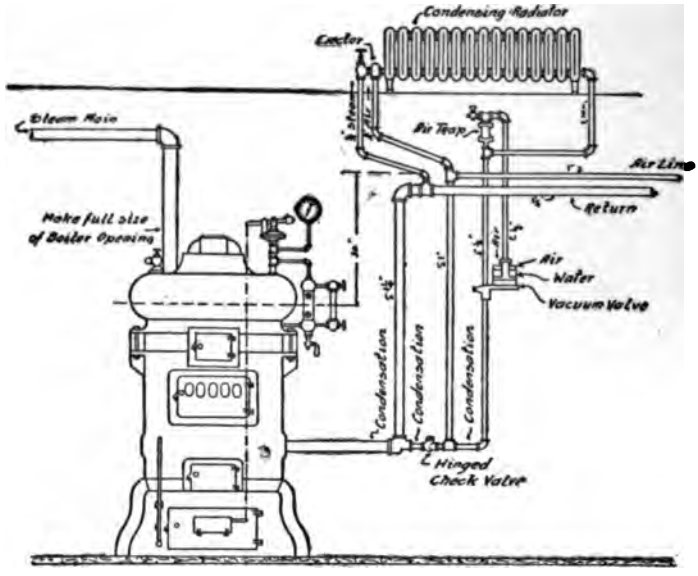


Fig. 105. Moline Vacuo-Vapor System of Heating.

quite similar to other vacuum systems—that is, in so far as the steam supply and air-line are concerned. The air and steam in the air-line are taken to a condensing radiator; and an ejector placed between the supply valve and the radiator creates the necessary pull on this air main. Fig. 105 illustrates the system clearly.

Note that from the condensing radiator, the air enters an air-trap which permits it to escape, but which closes against the flow of steam and water. The air from the trap is discharged through a vacuum valve having a perforated bottom and placed in a copper receptacle half-filled with water, which results in sealing the system against the return of the air. In discharging to the atmosphere, the escaping air bubbles up through the water in the receptacle.

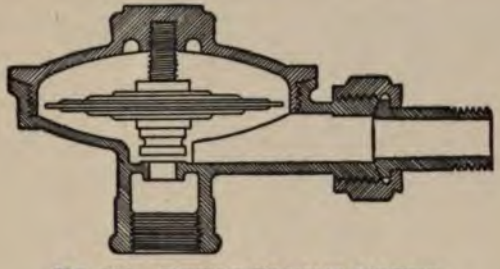


Fig. 106. Dunham Radiator Air-Trap.

The **Dunham plan** calls for the use of a system of flow and return piping without the addition of air-valves. On the return end of each radiator is placed an appliance called a **radiator air-trap**, as illustrated in Fig. 106, the device possessing the attributes and action of a thermostat. It is open to allow all air and water to escape from the radiator, closing against any escape of the steam. The water and air are taken through the return to a receiving tank located above the boiler, the supply of the latter leaving the system through a vacuum valve and passing to the atmosphere,

the water entering the boiler through the return. Fig. 107 shows the application of this system. Condensation passes to the receiving tank only after its heat has all been given up. Here it

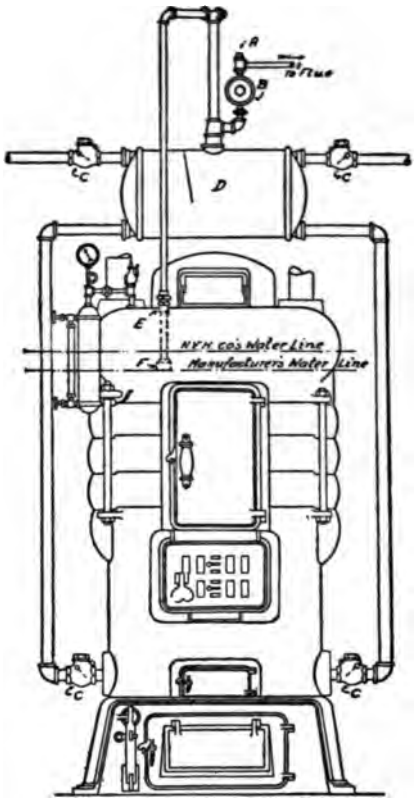


Fig. 107. Dunham Vacuum System of Heating.

accumulates until such a quantity of water has been evaporated from the boiler as will lower the water-line sufficiently to uncover the end of the equalizing tube F, which connects through

the boiler coupling E, forming a loop over and down into receiving tank D.

This opens a passage for live steam to enter the tank from the boiler, and equalizes the pressure therein with that in the boiler, thereby permitting this water to flow down into the return pipes and through check-valves C into the boiler, raising the water-line, and again covering tube end F and protecting it against the passage of steam by water seal.

After the discharging process, the steam which displaces the water in the receiving tank condenses, forming a partial vacuum therein, which relieves the check-valves C on the end of the return pipes entering the same, and permits accumulated air and water of the return pipes

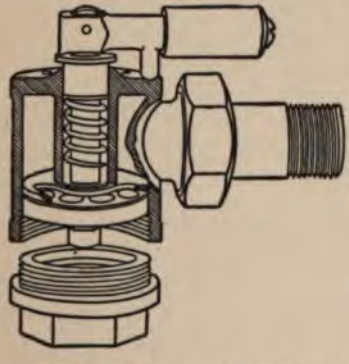


Fig. 108. Section of Quintuple Valve Used in Broomell System of Heating.

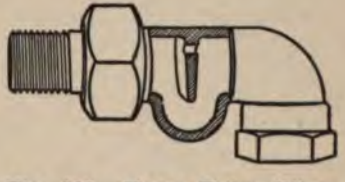


Fig. 109. Vapor Union Elbow as Used in Broomell System of Heating.

to be forced into this receiver, at the same time relieving them of any pressure and putting them under the same partial vacuum conditions

which may exist in the receiving tank at this time.

The **Broomell system** is a vapor method; that is, the pressure never exceeds ten ounces. A special form of valve, called a **quintuple valve** is applied on each radiator, its application permitting of a sufficient amount of vapor to be admitted to the radiator in order to fill it one-fourth, one-half, three-fourths, or entirely, as the case may be. Fig. 108 is a sectional view of this valve, showing the four holes or ports through the disc, which engage with similar ports through the seat of the valve. On the return end of each radiator is placed a special type of union elbow, Fig. 109, so constructed that it holds in check the vapor while the condensation is discharged into the return lines. The system of piping erected is in accordance with the two-pipe plan.

The real heart of the Broomell system consists of the combined receiver, draught regulator, and relief apparatus, shown in Fig. 110. The system is open to the atmosphere through the receiver, making it impossible for the pressure at any time to exceed ten ounces; and by reason of the action involved, the fire is automatically controlled.

The piping for a vacuum job must be absolutely tight throughout, in order to insure that no air can leak into the system and destroy the vacuum carried. For this same reason, the stuffing-boxes of all attached valves should be

perfectly tight; or, better still, special packless types should be used. The boiler should be supplied with a compound pressure and vacuum

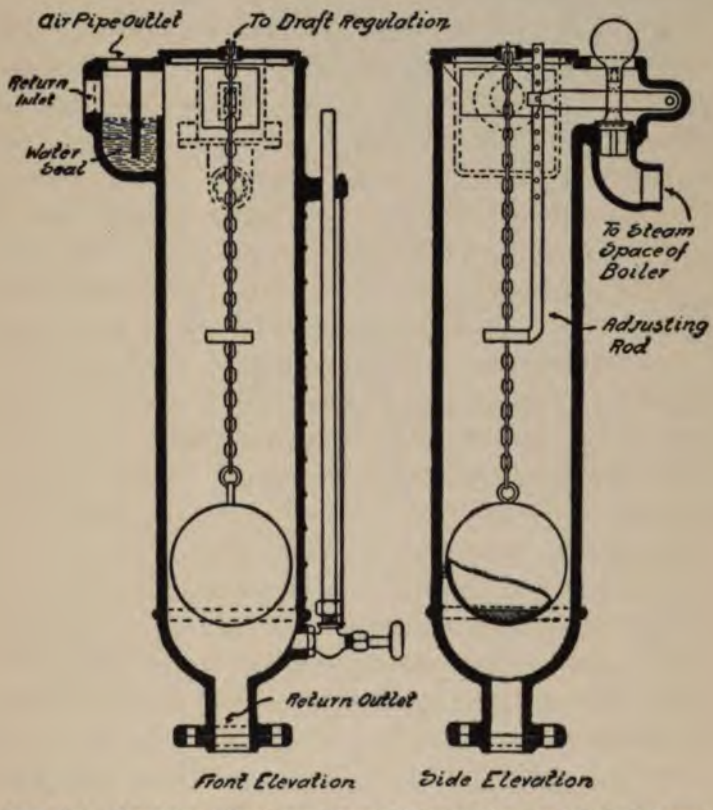


Fig. 110. Combined Receiver, Draught Regulator, and Relief Apparatus Used in Broomell Vapor System of Heating.

gauge; and for small air-lines, the pipe and fittings prove more suitable if galvanized.

Heating by the vacuum plan is sure to prove economical, because no steam pressure is necessary to drive the air from radiators when

once it has been removed. Again, all heating surfaces are effective, due to the complete withdrawal of any accumulated air and of the water of condensation.

The advantages of vapor and vacuum heating are many; and as the evident benefits derived from their usage are more and more understood by the heating contractor and house-owner, such systems will be adopted to a much greater extent than heretofore. The ability to generate and circulate steam at reduced temperatures (practically as low as those employed in hot-water heating), together with the fact that by a complete removal of air **all radiating surfaces are effective,** insures an immense saving in fuel as compared with the cost of operation of a job installed according to ordinary methods.

Table X gives the boiling point of water at different pressures, from complete vacuum (29.74 in. in the mercury column) to steam at 4.3 pounds pressure, or an absolute pressure (considering that of the atmosphere as 14.7 lbs.) of 19 pounds.

When it is fully comprehended that on the steam job as ordinarily installed no results are obtainable through the medium of the radiators until the atmospheric pressure of 14.7 pounds has been exceeded, since two pounds pressure, for example, at the boiler, means an absolute pressure of 16.7 pounds (14.7 + 2), we recognize the great waste of heat units in the fuel

TABLE X

Boiling Point of Water at Different Pressures

Vacuum Gauge (Inches of Mercury)	Absolute Pressure (Pounds per Sq. In.)	Temperature (Fahrenheit)
29.74	0.089	32.0 degrees
29.67	0.122	40.0 "
29.56	0.176	50.0 "
29.40	0.254	60.0 "
29.19	0.359	70.0 "
28.90	0.502	80.0 "
28.51	0.692	90.0 "
28.00	0.943	100.0 "
27.88	1.0	102.1 "
25.85	2.0	126.3 "
23.83	3.0	141.6 "
21.78	4.0	153.1 "
19.74	5.0	162.3 "
17.70	6.0	170.1 "
15.67	7.0	176.9 "
13.63	8.0	182.9 "
11.60	9.0	188.3 "
9.56	10.0	193.2 "
7.52	11.0	197.8 "
5.49	12.0	202.0 "
3.45	13.0	205.9 "
1.41	14.0	209.6 "
Gauge Pressure (Pounds per Sq. In.)		
Atmospheric pressure	14.7	212.0 "
0.304	15.0	213.0 "
1.3	16.0	216.3 "
2.3	17.0	219.4 "
3.3	18.0	222.4 "
4.3	19.0	225.2 "

consumed, the circulation never getting above the first floor unless a pressure of steam is constantly maintained on the apparatus.

The ability to use this otherwise lost heat by circulating it through the heating system, as is the case with vacuum and vapor heating, results in a saving of from 20 per cent to 40 per cent, according to the conditions surrounding the work.

Ventilation

By **ventilation** is meant the process of changing or renewing the air in a building in order that the supply may remain as pure as possible and be in such a state as to be healthful for breathing purposes. This is a subject which, unfortunately, until recent years, has commanded too little attention from all parties who should be vitally interested; and the acquisition of a perfect system of ventilation has been generally regarded as a luxury rather than the necessity it has proven to be. Ventilation is of even greater importance than heating, and we are fast coming to realize this, making provision for it as we recognize its worth. No architect solicitous of his standing would to-day plan a theater, church, public hall, school, or similar building which is intended to be occupied by a large number of people at the same time, without making adequate provision for the removal of the foul air within and the substitution of pure air from without for breathing purposes. And yet, of the thousands of dwellings erected each year throughout the country, we are warranted in stating that not even so large a proportion as one in one hundred has any special method applied for ventilating purposes.

The time is coming, and that not far distant, when no dwelling of any size, of the least im-

portance, will be constructed without provision being included whereby the occupant may periodically remove the foul air and admit a pure supply.

How Air is Contaminated. In order properly to understand how the air we breathe is contaminated or rendered foul and unfit for breathing, it is necessary to know the composition of air.

The earth is completely surrounded by an envelope of air or atmosphere several miles thick. This gaseous covering forms, as it were, a vast ocean, at the bottom of which we live and move. The substance of the air is a mixture consisting principally of oxygen and nitrogen, in the proportion of about one part (by volume) of the former to four parts of the latter, with a very small proportion (about three or four parts in ten thousand) of carbonic acid gas. Carbonic acid gas results from all combustion—being produced in considerable quantities even by that form of combustion which takes place in animal respiration. Oxygen is the life-giving quality in the atmosphere, without which all living things would die. The oxygen in the air within a room is consumed by the burning of illuminants—such as candles, coal oil in lamps, and gas—and also as a result of the process of breathing.

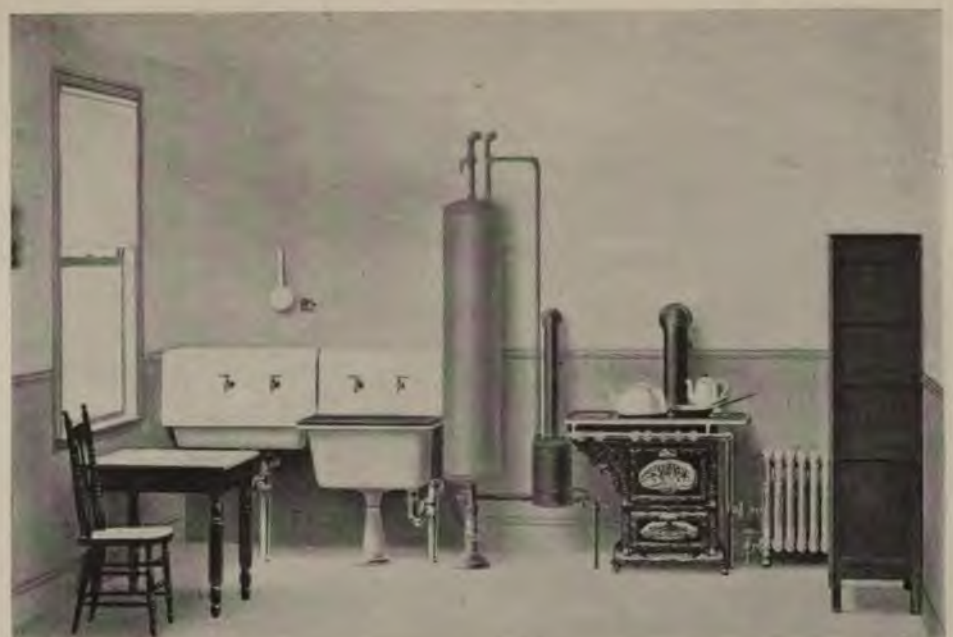
In addition to the above substances, there is also present in the atmosphere more or less aqueous vapor or moisture, the amount varying

with the condition of the weather or the proximity of the air to a body of water. We use the term **humidity** to express this ingredient, and the term **relative humidity** to indicate the relation existing between the moisture actually present in the air and that which would be present were the air completely saturated.

Carbonic acid gas is not in itself always harmful, as its presence in soda water and other carbonated drinks will attest. However, when breathed into the lungs in the process of respiration, and when the oxygen breathed with it is consumed, the exhalations from the lungs contain poisonous matter, and the continued breathing of many people confined within a room will in time so vitiate the atmosphere as to render it dangerously baneful.

Air is vitiated or contaminated, then, by the burning of illuminants, as before noted, and by the exhalations of the people inhabiting the room or building. It may also be tainted by fumes and odors from certain chemicals, etc.

The amount of carbonic acid gas in the air we breathe should never exceed six or seven parts in 10,000. When present in greater proportion—say, ten or twelve parts in 10,000—there will be a feeling of closeness or stuffiness experienced by the occupants of the room, frequently causing fainting spells, headaches, etc. An eminent physician recently stated that the breathing of a plenteous supply of pure fresh air constitutes the best medicine to cure the ills of



A WELL-EQUIPPED MODERN KITCHEN FOR A SMALL HOUSE.
Gas Range, Gas Heater, Range Boiler and Combined Sink and Laundry Tray.

mankind—notably so, the dread one of tuberculosis (consumption) and allied maladies. Aside from its curative powers, pure air is also an efficient preventative of sickness.

How Ventilation is Secured. In discussing the methods for securing ventilation, we shall not here describe at length the mechanical devices used in large buildings, except to say that by means of a **fan** or **blower, air-washer, etc.,** it is now possible to furnish a supply of pure, humid atmosphere within any building, regardless of how densely occupied or of the condition of the air outside. We can truly claim that we are now able, with modern appliances, to furnish any condition of climate for any sort of purpose.

It is the ventilation of homes that we wish more particularly to discuss, urging upon our readers the importance of following what suggestions we have to offer for accomplishing results in this respect. A large part of our lifetime is spent in the sleeping room—probably one-third of each twenty-four hours—and hence all rooms devoted to this use should be well ventilated.

In all efforts exerted to secure ventilation in a room, two things are necessary—first, the admission of pure air; and second, the removal of foul air. The accomplishment of the former result is an easy proposition; of the latter, a comparatively hard one. All modern dwellings are so constructed with archways of large doors

between principal rooms that one indirect radiator, as shown in Fig. 75, placed under the central hall, and one or two others located under the principal rooms, will admit plenty of fresh, pure air to the first floor of the dwelling.

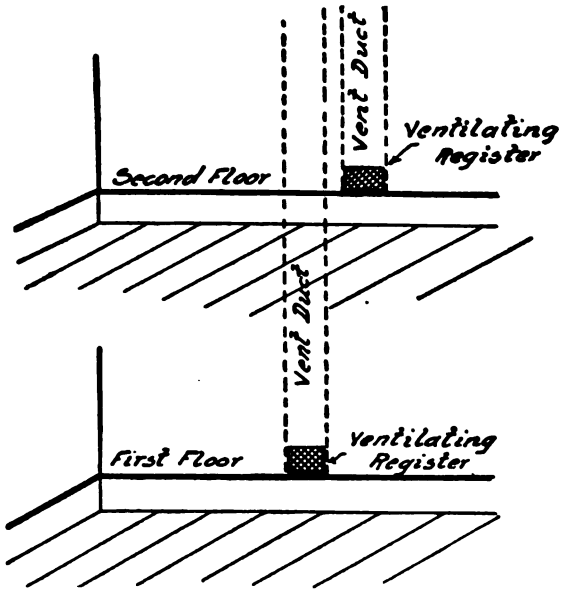


Fig. 111. Good Location of Ventilating Registers.

For second-floor rooms, or those in isolated locations, direct-indirect radiators may be installed, as shown in Fig. 74, as a means to secure the desired service.

It is a difficult matter to exhaust the foul air unless suitable flues are provided for this purpose while the building is in course of erection. It is a good plan, in building, to erect ventilating flues in pairs—one of the two extending down to

the floor of the second-floor rooms, the companion flue reaching to the first floor. Registers should be placed in the flue in each room, near the floor. A good location is at a point just above the baseboard, as illustrated in Fig. 111. These flues should extend upward to the atmosphere.

The warm, pure air admitted to the room through the radiator is light and buoyant, and rises to the ceiling, settling gradually below the breathing-line to the floor as it becomes heavy during the process of cooling. This supply below the breathing-line is the foul or contaminated air, and must be removed at or near the floor-line.

A cold shaft or chimney is of no use whatever for ventilating purposes, as it is open to the atmosphere and has the pressure of the outside air (14.7 lbs.) constantly pressing down upon its contents. To create an upward draught or current in the flue, in order to overcome the atmospheric pressure, it is necessary to heat or expand the air in each flue, and the warming of this supply may be accomplished in various ways.

Probably the simplest method in connection with a steam or hot-water heating apparatus is illustrated in Fig. 112. A pipe riser is carried up near to the flue, and a branch on each floor run to a small coil or line of pipe inserted in the flue above the register. A small air-pipe leading from the top of the coil into each room

terminates at an air-vent through which the air in the coil is removed. When the heating apparatus is in operation, this arrangement will

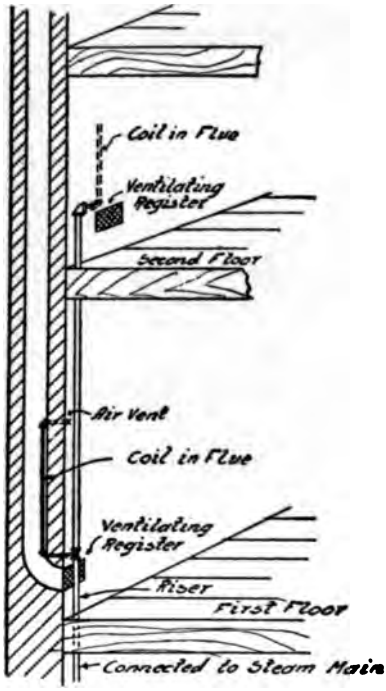


Fig. 112. Placing a Coil in Ventilating Flue to Force Circulation.

be found to afford a very satisfactory method for securing ventilation.

Another method, which may be adopted in a dwelling with a large attic, involves having the ventilating flues terminate just above the attic floor, where they are connected by galvanized ducts into a large ventilating shaft opening through the roof, this shaft being supplied with a sufficient amount of heat to expand the air.

The construction for the heating of the air may be in the form of a large radiator or coil. A further advantage derived from the usage of this method is that ventilation may be secured in summer months when the heating apparatus is not in use, simply by the introduction into the shaft of a fan, electrically connected, for exhausting the foul air to the atmosphere. If desired, this fan arrangement can properly be used all the year round, and the pipe coil in the flue omitted.

Still another method which may be practiced with success in compactly erected residences, requires the building of a large brick shaft through the center of the house. A smoke-pipe for the heating apparatus—made of iron or steel, or of terra-cotta pipe with tightly cemented joints—is carried through the center of the shaft, furnishing the heat to expand the air in the shaft, this provision producing an upward current. All ventilating ducts are then connected into this shaft, either directly on each floor, or are carried to the attic for connection.

One benefit included in the use of either of the latter two methods is that the ventilating ducts may be constructed of tin and inserted in the partitions in quite the same manner as would be the hot-air riser pipes for furnace heating work.

As a rule, dwellings are easier to heat when provision is made for exhausting the heavy, foul air within. This is particularly true in furnace

or hot-air heating, as it is impossible to circulate warm air into or through a perfectly tight room from which no supply can escape.

TEMPERATURE REGULATION

No heating apparatus can be considered fully complete unless equipped with some form of device which provides a method for automatically regulating the draught and check doors of the heater to accord with the varying temperatures of the rooms in the building. However, only a small percentage of heating apparatus now in use is supplied with such appliances.

Temperature-controlling devices usually include a **thermostat**, which is placed in one of the living rooms (a place in which a regular, uniform degree of temperature is desired) and connected to a form of motor or similar agent, to furnish the power necessary for operating the dampers of the heater.

Of all the accessories to a heating appliance which assist in insuring its economical and satisfactory operation, there is no other one to be compared with an adequate system of temperature regulation.

While all low-pressure steam boilers are provided with a draught regulator of the type illustrated in Fig. 88, hot-air furnaces and hot-water heaters, as a rule, have no such provision for draught control. The operation of the regulator of a steam boiler is not governed by the temperature of the room; it simply regulates the

draught doors of the boiler according to the motive force of the pressure of steam within, and, by reason of this action, cannot be considered strictly a temperature-regulating device.

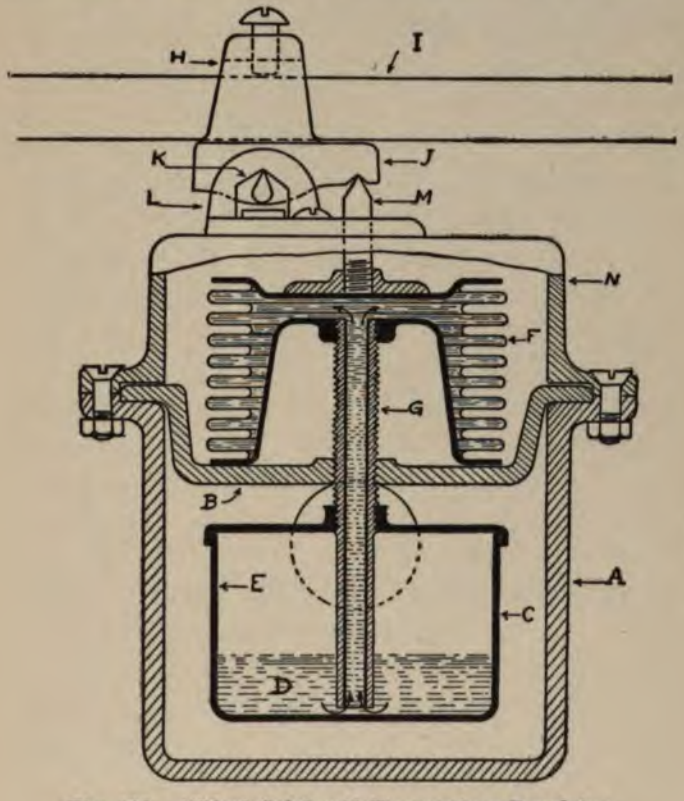


Fig. 113. "Ideal Sylphon" Temperature Regulator.

For use on systems in residences and on ordinary heating work, the temperature-regulating devices adaptable can be divided into two classes—(a) those that are controlled by the temperature of the water within a hot-water

heating system; (b) those controlled by the temperature of the atmosphere within the building.

There are several styles and types of each, but we can describe here only one or two of the representative regulators in each division. Of those in Class (a), above, the "Ideal Sylphon" shown in Fig. 113 is a good illustration. It will operate at any desired temperature ranging from 120° to 180° F., and may be adjusted by simply moving a weight on the lever rod. In its construction the cast-iron pot A is divided horizontally by the partition B. The lower compartment contains the bulb C, which holds a volatile liquid vaporizing at a low temperature and filling the space E. This bulb is made of a metal having a high conductivity for heat, which allows slight variations of temperature to penetrate quickly to the volatile liquid. The water from the heating system flows through the space between A and C, completely surrounding the bulb C. The upper compartment contains a metal bellows F, which is hermetically sealed and which communicates with bulb C through pipe G. The construction of the rocker and lever are shown by H, I, J, and K.

As the temperature rises, the vapor in space E increases in pressure, forcing a portion of the liquid up pipe G into the bellows, as indicated by arrows. This action causes the bellows to expand, raising the plunger M, which, in turn, tilts the rocker and lever, whose ends are at-

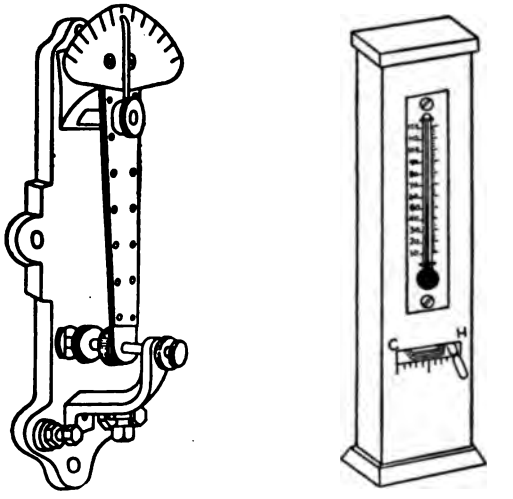
tached to the draught and check doors by chains, gradually closing the draught door and opening the cold-air check. As the temperature falls, the reverse action occurs.

Probably the first successful device employing the vapor obtained from a volatile liquid was the "Powers" regulator. As at present produced, this regulator is made in a variety of forms for use in controlling the draughts of a furnace as well as steam and hot-water heating apparatus; and while, in its mechanical parts, it differs from the "Sylphon," previously described, the principle of procuring the necessary power from the vapor of a volatile liquid is practically identical.

The regulators in Class (b)—those controlled by the temperature in the heated room—are of two general kinds, which we may properly term (1) **electric,** and (2) **non-electric.** Among the former are the "Minneapolis," the "Honeywell," the "Jewell," the "Beers," and the "Beckam."

All regulators of the electric type require the use of a thermostat, which is located in a living room and is connected by wires or chains to a motor in the cellar placed near the heater. The thermostat employed usually consists of a metal frame holding some form of metal or other substance very susceptible to variations of heat and cold. When expanded by heat, this substance is thrown against a pin, by this movement closing the electric circuit to the motor,

which then operates to close the draughts of the heater. When the temperature of the room falls, the substance contracts and is cast back against another peg, whereupon an action the



Open Type. Enclosed Type.

Fig. 114. Beckam Thermostat.

reverse of the above occurs. Fig. 114 shows two types of the Beckam thermostat.

The motor may receive its power from a spring wound up within it; or, as in the Beckam types, the force to drive the motor may be generated by a weight wound up daily in much the same manner as a Swiss clock. Fig. 115 illustrates the Beckam motor; and Fig. 116, the method used for attaching the various parts to the heater, the light dotted lines showing how the connections are made to a steam boiler.

The non-electric regulators, of which there

are many individual types, involve the use of power derived from the expansive force of metals, rubber, or liquid. In this class we have

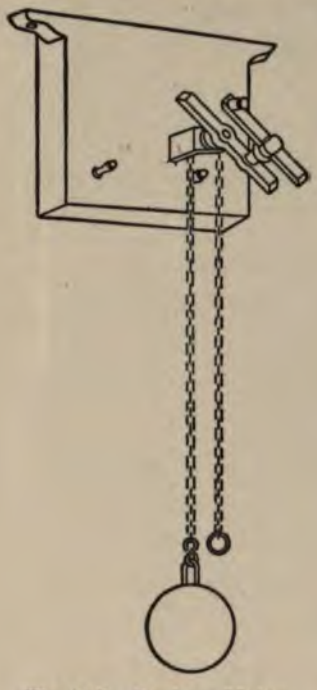


Fig. 115. Beckam Motor.

the "Regitherm," a regulator in some respects similar in principle to the "Sylphon," already described, using a volatile liquid and a metal bellows; the "Powers," with a volatile liquid; the "National," having the rubber in its thermostat; the "Howard," using a triangular disc of a rubber composition, which is fastened on the lower side, the point of the triangle being free for moving back and forth by expansion

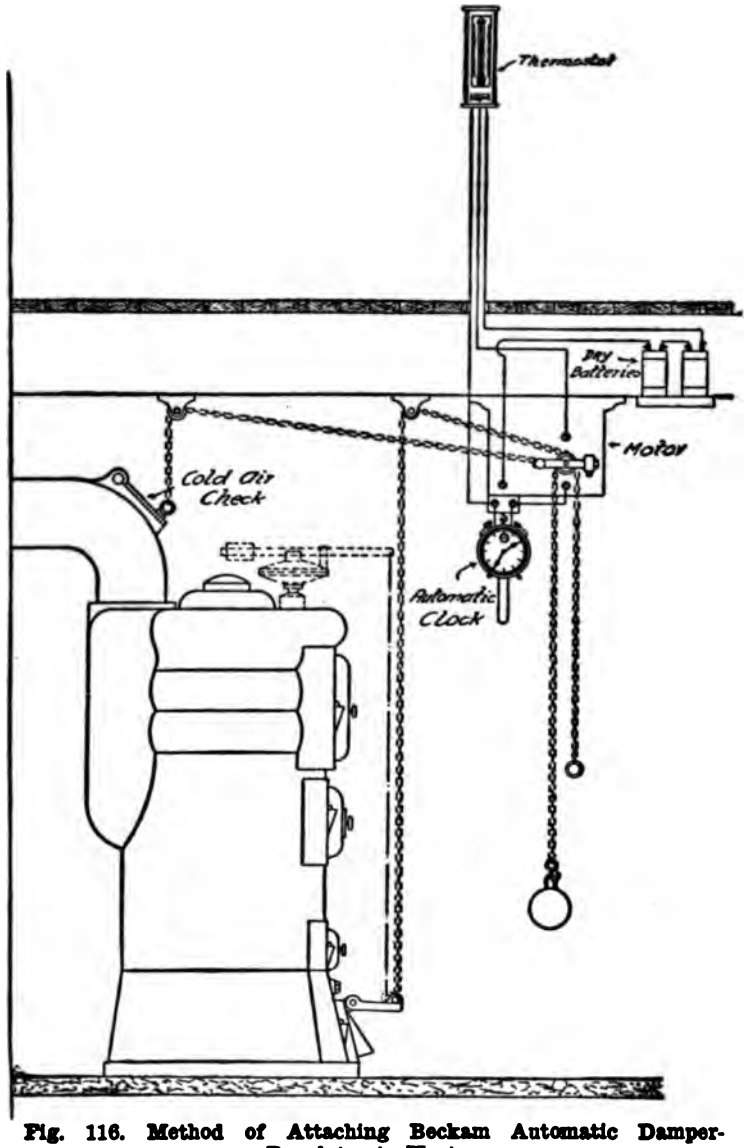


Fig. 116. Method of Attaching Beckam Automatic Damper-Regulator to Heater.

and contraction from the effects of heat or cold.

The thermostats and motors of the different types, while varying somewhat in principle, all aim to accomplish the same purpose—namely, the furnishing of power to open or close the draughts of the heater.

Practically all thermostats will work accurately within a margin of two degrees from the desired temperature; for instance, with the indicator set for 70° in the room, the temperature will not rise above 71° before the regulator will check the fire; and prior to a fall of the temperature in the room to 69°, the regulator will again operate to open the draughts on the heater.

The extent of the saving in fuel within one, two, or three years, according to the size and character of the job, will pay for a first-class thermostat, after which length of time its usage will annually help to meet the cost of the fuel bill.

PIPE AND BOILER INSULATION

The thorough insulation or covering of all piping on a steam or hot-water heating apparatus, as well as the covering of all exterior surfaces on the boiler or heater not occupied by the various pieces of plate-work (the clean-out, fire, and draught doors, the frames, jacketing, etc.), is essential to the economical operation of the apparatus. Tests have conclusively proven that the insulation of such surfaces effects a

saving of from fifteen to thirty per cent, the amount depending upon the character of the covering applied.

To be of good quality, the insulation must consist of such material as will prevent the escape of heat outwardly between the pipe and the surrounding atmosphere. As a matter of fact, heat may be lost or dissipated from the hot surfaces of the pipe or heater in three ways—

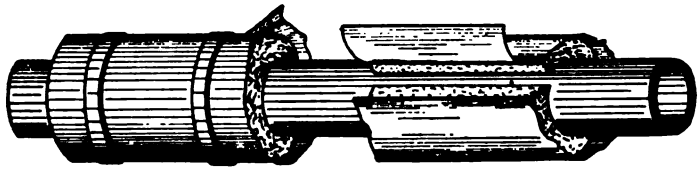


Fig. 117. Illustrating Method of Fastening Pipe Covering in Place by Means of Metal Bands.

namely, by **radiation,** by **conduction,** and by **convection.** The effects of these, however, can be partially or entirely overcome by the covering.

The materials which have been most generally used for the purpose of insulation are **asbestos, hair felt, mineral wool, cork, magnesia, pressed paper,** and **sawdust.** Pipe covering as furnished to-day is manufactured in three-foot lengths, split lengthwise for ease of adjustment on the job, and covered with muslin or canvas pasted over the cut. It is fastened securely in place by iron or brass lacquered bands, Fig. 117 illustrating the method.

For high pressures and superior work, a moulded covering composed of about 85 per cent

magnesia, with the remainder of fiber asbestos and similar fireproofing materials, is generally adopted.

For ordinary low-pressure heating and for hot-water work, a less expensive covering may be employed to insure satisfactory results. On such jobs, several layers of felt paper lined with asbestos, or strips of corrugated asbestos, or a covering made of ground cork, can be employed to advantage. Felt or asbestos paper specially wound to form air cells running

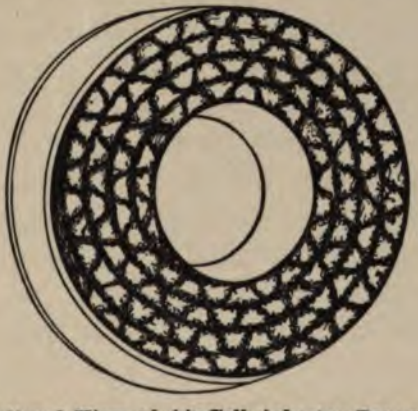


Fig. 118. Sectional View of Air-Cell Asbestos Paper for Covering Pipes.

lengthwise with the piping, affords a practical covering. Fig. 118 shows a cross-section of this type.

To obstruct the passage of radiant heat presents no difficult problem, and almost any non-conducting substance will suffice to accomplish the purpose. To prevent loss by convection and conduction is, however, a different proposition.

The heat from the steam or water is imparted to the inner surfaces of the pipe by contact; and iron being an excellent conductor, the heat is quickly transmitted to the outer surface, and it is at this part of the pipe that the great loss occurs. The heated pipe in this respect acts in exactly the same manner as a radiator or coil placed in a cold room. The air immediately surrounding the pipe is heated by contact, and rises above the pipe by reason of its lower specific gravity. The cold air replacing it is in turn heated, too, this process of radiation of heat continuing as long as there is any hot water or steam in the pipe, when in an uncovered condition. It is to prevent this great and continual loss that all piping should be thoroughly covered. To be of effective service in overcoming this loss, the covering must fit snugly against the pipe.

Hair felt, asbestos (which is a natural, fibrous rock, whose fibers have been separated and broken up), magnesia, and cork have a low thermal conductivity, for this reason being more efficient for insulating purposes than other materials.

It is customary to protect boiler or heater surfaces with a lagging consisting of a plastic covering composed largely of asbestos and magnesia in the form of a cement, which is plastered upon the exterior portions to be covered, while they are hot. This method of application insures a hard and firm covering when dry.

BATHROOM WITH MODERN EQUIPMENT FOR A SMALL HOUSE.

Plumbing

It is the intention, in the following pages, to show the latest and best methods of installing plumbing, avoiding, as far as possible, technical terms that might tend to confuse the mind of the average workman—in other words, to describe in simple language and in the most direct and practical manner the various stages in the installation of plumbing systems from start to finish.

SEWER AND CONNECTIONS

About the first thing to be considered in the layout of any plumbing is the **Sewer.** This is usually constructed of salt-glazed vitrified sewer-pipe, laid to an even grade, with the joints well cemented with Portland cement and clean sharp sand in the proportions of 1 part cement to 2 parts sand, and all joints carefully cleaned on the inside of the pipe after cementing, to prevent waste matter catching on the edges of cement which will be formed at each joint when the pipes are butted together. Fig. 1 shows the manner of using a "swab" for this purpose. This swab may be made of a stick

with nails driven in it, and then cloth wound tightly around it and securely fastened on. The swab should be the full size of the pipe to insure the thorough removal of the cement.

Connections to the main sewer are usually regulated by local conditions and rulings; and this matter need not be discussed further than to state that a connection should never be made with a "tee" joint, but should be made with a

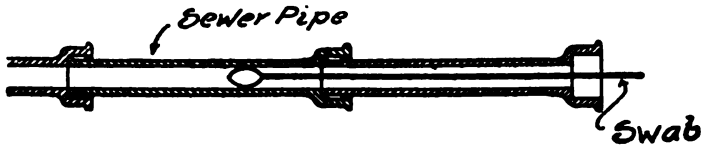


Fig. 1. Manner of Swabbing Inside of Sewer Pipe.

"Y;" or, when the main sewer has no Y connection, the entrance to the sewer should be made in such a manner that the sewage will strike at an angle in the direction in which the main sewer flows.

The sewer pipe will continue toward the building with a gradual pitch up to same, and should terminate at a point not less than 5 feet from the building at which point it will be extended into the building with cast-iron soil-pipe, and—for the slight difference between the "Standard" and "Extra Heavy" grades in cost —preferably with the Extra Heavy.

Sewer Traps and Ventilation. The necessity of a **house, main,** or **intercepting trap** in the sewer line is a question that has called forth considerable discussion both for and against the

use of such a device; and both sides have their good and bad points. Local rulings usually govern this feature. Whether trap is used or not used, the soil-stack or stacks should always extend up to and through the roof, and should never be inserted into a chimney as is too often done. The chimney was built to serve the purpose of a chimney, and not as a vent for the plumbing system.

Rain Water Pipes. When rain leaders or downspouts are connected to the sewer, the proper size of pipe can be determined from Table I, which is based on an average rainfall. All leaders should be trapped at their base.

TABLE I

Sizes of House Drains to Carry Rain Water

Size of Pipe	One-Fourth Inch Fall per Foot	One-Half Inch Fall per Foot
5 in.	3,700 Sq. Ft. of Roof Area	5,500 Sq. Ft. of Roof Area
6 "	5,000 " " " " "	7,500 " " " " "
7 "	6,900 " " " " "	10,000 " " " " "
8 "	11,600 " " " " "	15,600 " " " " "
9 "	11,600 " " " " "	17,400 " " " " "

An easy rule to remember is to allow 1 square inch in pipe area for each 250 square feet of roof area.

Cistern Overflows. A cistern overflow should never be connected into the house sewer if it can be avoided, as there always exists the possibility of the sewer choking or clogging up and backing into the cistern. Sickness usually results before this is noticed, if there are no fixtures in the basement to overflow and thus denote the stoppage. It is much better to allow

the overflow is run out upon the surface of the ground. As houses are usually built on a higher elevation than the street level, the overflow may terminate in the street gutter. When the cistern overflow must go into the sewer, a good connection can be made as shown in Fig. 2.

Sizes of Sewers. Regarding the proper size of sewer to put in for the various installations, it should be borne in mind that it is always good practice to avoid putting in a sewer too large,

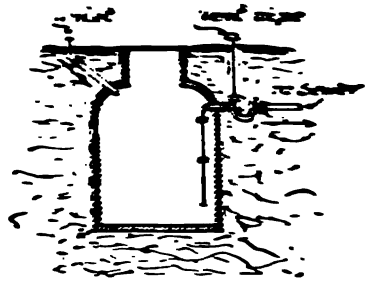


Fig. 2. Connecting Cistern Overflow to Sewer.

or giving same too much pitch. It is better practice to install a size that will be flushed, or nearly so, by the water flowing through it, than to put in a size in which the water will never reach higher than part way up the sides, since the latter have a tendency to allow the floating matter to adhere to the sides, and in time the accumulation may cause a stoppage.

For example, it is better to use a 5-inch sewer-pipe than a 6-inch, when the soil-pipe is 4-inch. It is good practice to run the sewer-pipe one size larger than the soil-pipe which dis-

charges into it, on account of the frictional resistance being greater in the clay sewer-pipe than in the cast-iron soil-pipe. The water that fills the 4-inch pipe would not fill a 5-inch pipe to the same height, while a 6-inch pipe would be filled still less, and thus the thorough flushing of the larger sized pipe is made impossible.

Also, by giving the sewer too much pitch, the water travel may be so rapid that the water will run ahead of the solid matter, allowing the same to be deposited in the pipe to present an obstruction to the next discharge of matter through the pipe. The average fall which is given sewer- and soil-pipes, of ¼ inch per foot, is more than ample. Table II shows the fall required in different-sized sewers to give an average velocity of 276 feet per minute in the flow of sewage—which velocity of flow will carry all matter from the sewer.

TABLE II

Fall per Foot for Various-Sized Sewers

Size of Sewer	Fall or Pitch Required	Velocity of Flow
2 Inch.....	1 Foot in 20 Feet	276 Feet per Minute
3 "	1 " " 30 "	276 " " "
4 "	1 " " 40 "	276 " " "
5 "	1 " " 50 "	276 " " "
6 "	1 " " 60 "	276 " " "
7 "	1 " " 70 "	276 " " "
8 "	1 " " 80 "	276 " " "
9 "	1 " " 90 "	276 " " "
10 "	1 " " 100 "	276 " "

It must be borne in mind that the only way that sewage is carried along in the pipes is by flotation; and there is no other manner of doing

this. There is no hidden force in the sewer to carry away the sewage, and solid matter requires water to dispose of it. This again illustrates the fact that a 5-inch pipe, if large enough to carry the flow, is better than a 6-inch, as the water is deeper in a 5-inch than in a 6-inch pipe, supposing the same quantity of water to be discharged.

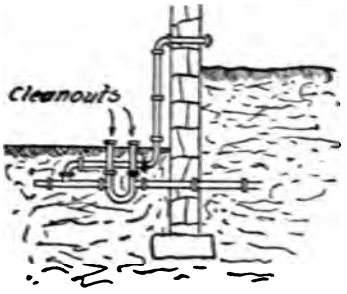


Fig. 3. Installing a Trap and Fresh-Air Inlet.

Particular attention should be paid to the making of the joint between the clay and the iron pipes. This may be done with one of the patented devices now on the market, or by cementing just as in the balance of the sewer piping. Leaky joints are a constant menace to the health of the occupants of the building.

Fresh-Air Inlet. When a main trap is used it should always be provided with a **fresh-air inlet,** usually 4 inches in size, which may be increased when necessary, for the purpose of relieving the air-pressure that may accumulate in the system, and to create a current of fresh air throughout the entire piping system. Fig. 3

shows a good method of installing a trap and fresh-air inlet.

It is better to introduce the fresh-air inlet at a point a short distance beyond the trap, as this avoids the possibility of the water-seal becoming frozen in winter, and also avoids or decreases the evaporation that will occur if the inlet is introduced directly into the hub on top of trap. It is good practice to use a trap with hubs for double vent, as this will allow cleanouts to be placed on both sides of the water-seal, and affords free access to the sewer for cleaning purposes.

ROUGHING-IN

As we now have the drain-pipe into the basement of the building, we are ready to **rough-in** the job, and a few words regarding the proper manner of handling soil-pipe will be useful.

Cutting Soil-Pipe. We shall have a number of pieces of soil-pipe to cut to various lengths as the job progresses, and the best way to cut the pipe is with a narrow, sharp-pointed chisel, and a medium-weight hammer. This gives better results to the average mechanic than the use of three-wheel cutters, on account of the liability to crack the pipe, which is very easily done with the cutters because of the pipe not being of uniform thickness throughout, and because with the cutters this variation in thickness cannot be so easily detected as with the hammer and chisel, the ear

being of great assistance in determining where the pipe is thick and thin. Lay the pipe on the floor, and place a narrow piece of wood under the place marked for cutting. The pipe should be marked with chalk entirely around at the place where it is to be cut. Then use the chisel and hammer. Filing a groove around the pipe where it is to be cut is not necessary, since the chisel will make a clean, square cut, as you will find, after a little practice.

Soil-Pipe Joints. Fig. 4 shows the proper manner of making a soil-pipe joint, and Table

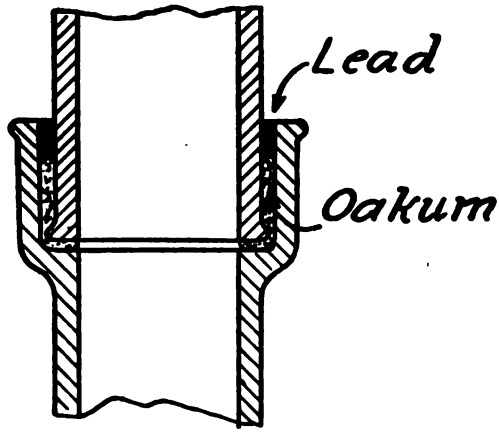


Fig. 4. Soil-Pipe Joint.

III shows the amount of lead and oakum required for the various sizes.

The proper method of making a soil-pipe joint is to carefully pack the same with oakum, and leave a space of 1¼ inches for the lead. The oakum must be calked tightly before pour-

TABLE III

Lead and Oakum Required for Soil-Pipe Joints

Size of Pipe	Lead per Joint	Oakum per Joint
2 inch.....	1½ pounds	3 ounces
3 "	2¼ "	6 "
4 "	3 "	7 "
5 "	3¾ "	8 "
6 "	4½ "	9 "

ing in the lead. If the pipe has not been cut exactly square across, care must be taken that none of the oakum is driven into the pipe to present an obstacle to the flow of waste matter and in time cause a stoppage. The joint will then be poured with the hot lead, in one pouring; and after the lead has cooled, it will be properly calked tight with the proper calking chisels and a light hammer, bearing in mind that at every blow of the hammer you are creating a pressure on the hub which may crack the hub unless the operation is carefully done. The joint should always be run full at one pouring; if this is not done, the lead should be picked out and the joint poured again.

Pouring lead in an upright joint is a very simple matter; but when we come to a horizontal joint, this requires different handling, and we have recourse to a **joint-runner** made of asbestos, which clamps around the pipe in such a manner that it leaves an opening on top for the pouring of the lead. Clay or putty may be used for this purpose, but are makeshifts and very unsatisfactory.

If there is dampness in the joints, placing some pulverized rosin in the hub before pouring will be beneficial.

Always have your lead **HOT**, and do not try to pour a joint with half-warm lead. Nothing but lead free from solder or other metals should be used, in order to avoid cracking the hubs when calking.

The Piping System. We shall have a number of pipes throughout the building to install; and they are as follows:

Drain pipes, which are horizontal and receive the discharge from the vertical or upright pipes.

Soil pipes, which receive the discharge from the closets.

Waste pipes, which receive the discharge from fixtures other than closets.

Vent pipes, which relieve the air pressure on the system, prevent siphonage and create a circulation of air throughout the system.

Water pipes, which supply water to the various fixtures.

We shall now proceed with the roughing-in of an actual job. Suppose that we are to install the plumbing in a house of which Figs. 5, 6, and 7 show the basement, first-floor and second-floor plans. The fixtures on the job are as follows:

Basement	1 Two-part Wash Tray.
	1 Floor Drain.
First Floor	1 Sink.
	1 Forty-Gallon Range Boiler.
	1 Lavatory.
Second Floor	1 Lavatory.
	1 Bathtub.
	1 Water Closet.

Right here is the time when you have to know the **roughing-in measurements** of the various fixtures, in order to place the pipes so that they will be in exactly the right places when the floors are down and the plastering done. Having deter-

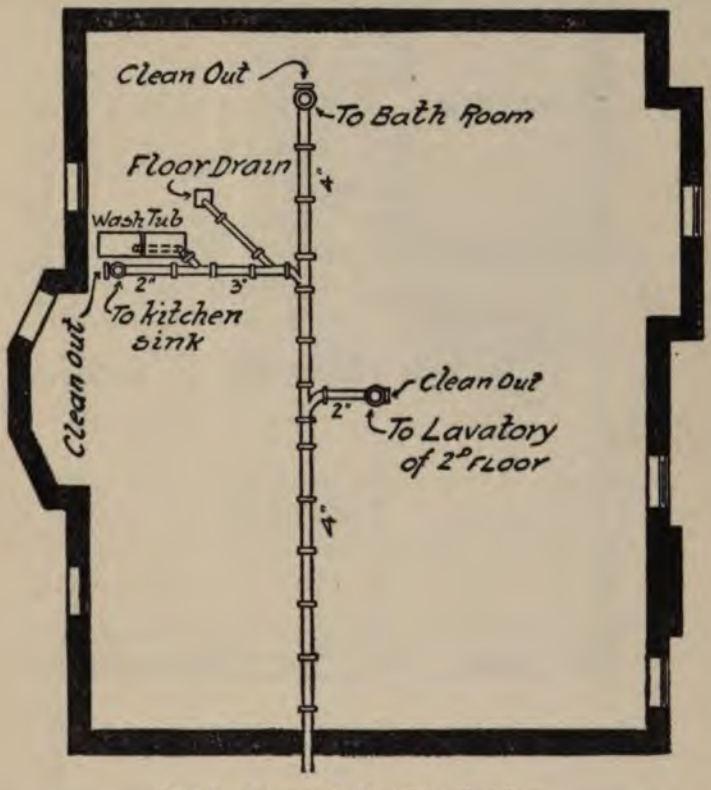


Fig. 5. Basement Roughing-In Plan.

mined what these measurements are to be, we are ready to proceed.

The plumber will find it a great help if he will jot down in a small memorandum book the

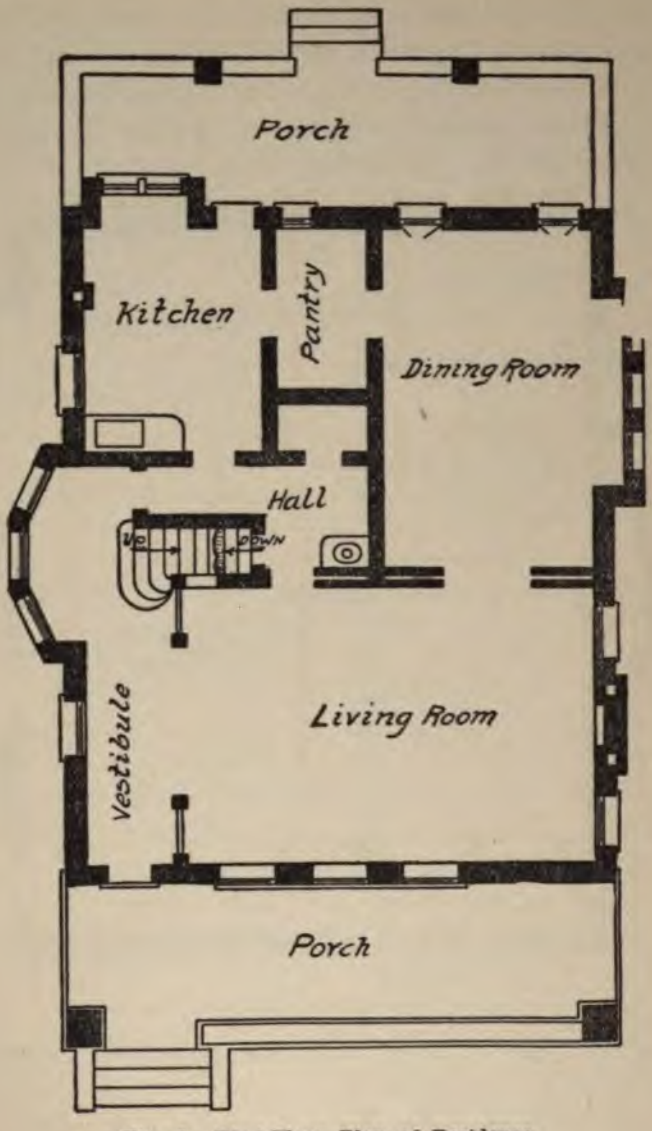


Fig. 6. First-Floor Plan of Residence.

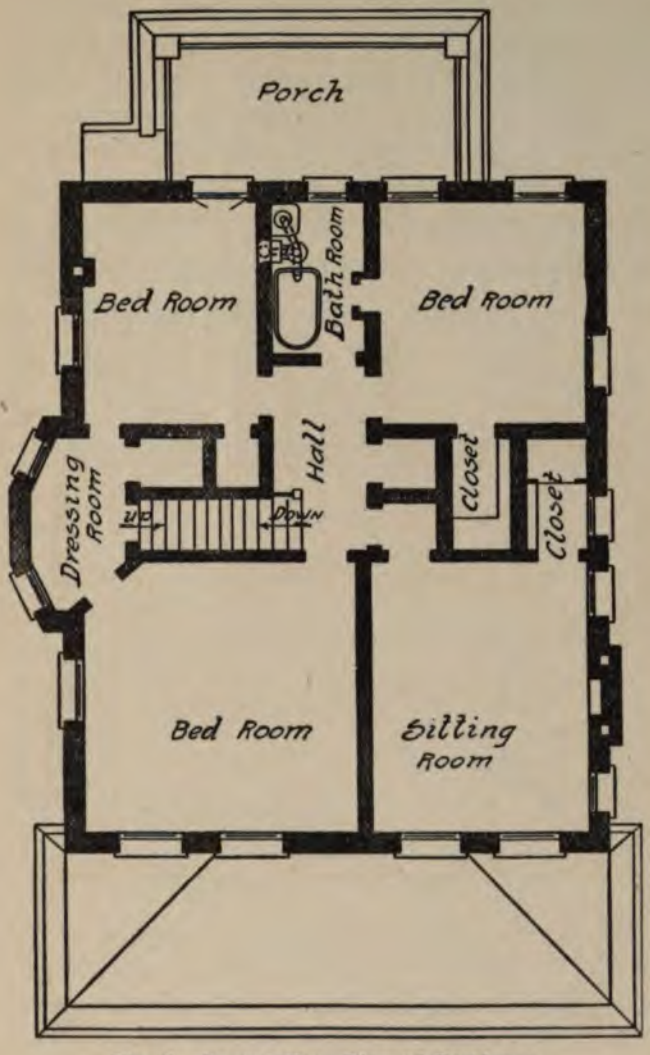


Fig. 7. Second-Floor Plan of Residence.

roughing-in measurements of every fixture he installs, for this will save the trouble of looking up in the future when he may have fixtures of the same style to install. Let us examine the fixtures that go in on his job, and note the measurements in our little book for future reference.

The **wash trays**—or **laundry tubs**, as they are sometimes called—are of the style shown in Fig.

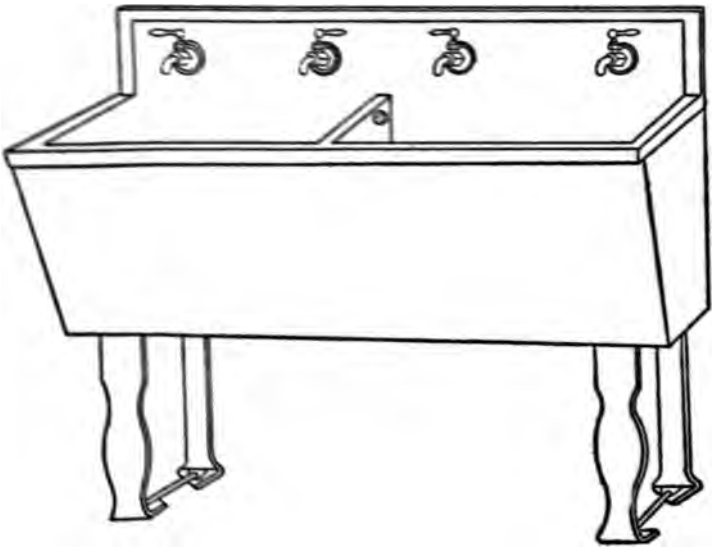


Fig. 8. Wash Trays or Laundry Tubs.

8, with rough brass continuous waste and trap as in Fig. 9; and are to be supplied with hot and cold water through Fuller bibbs, as shown in Fig. 8.

The **floor drain** is like that shown in Fig. 10.

The **kitchen sink** is of the type illustrated in Fig. 11, with nickel-plated trap, with waste to

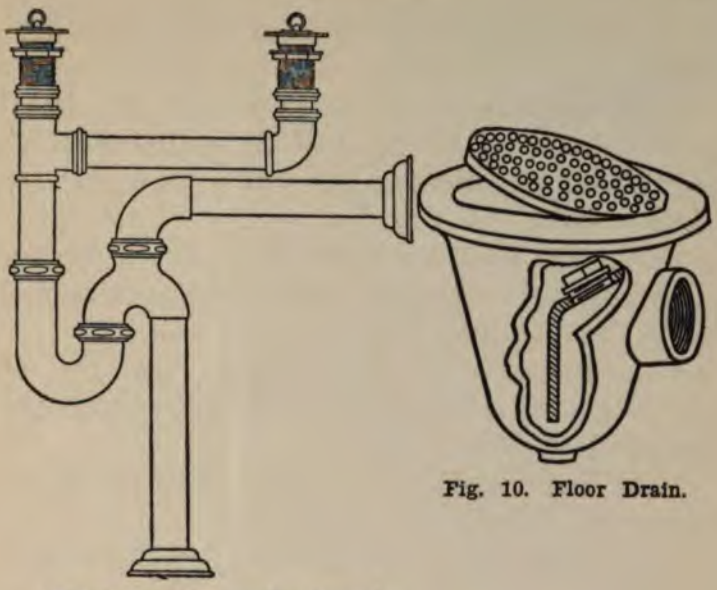


Fig. 10. Floor Drain.

Fig. 9. Continuous Waste and Trap from Wash Trays.

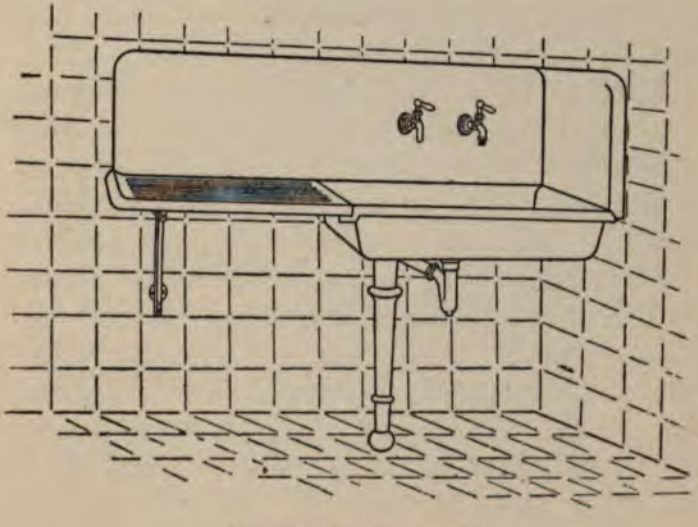


Fig. 11. Kitchen sink.

floor and vent to wall, and nickel-plated Fuller bibbs.

The **range boiler** is shown in Fig. 12. It is to be erected on a stand (Fig. 13), and connected to the **kitchen range**, and also to a **gas heater** as shown in Fig. 14.

The first-floor **lavatory** (Fig. 15) is fitted with nickel-plated Fuller basin corks, and nickel-plated trap to wall.

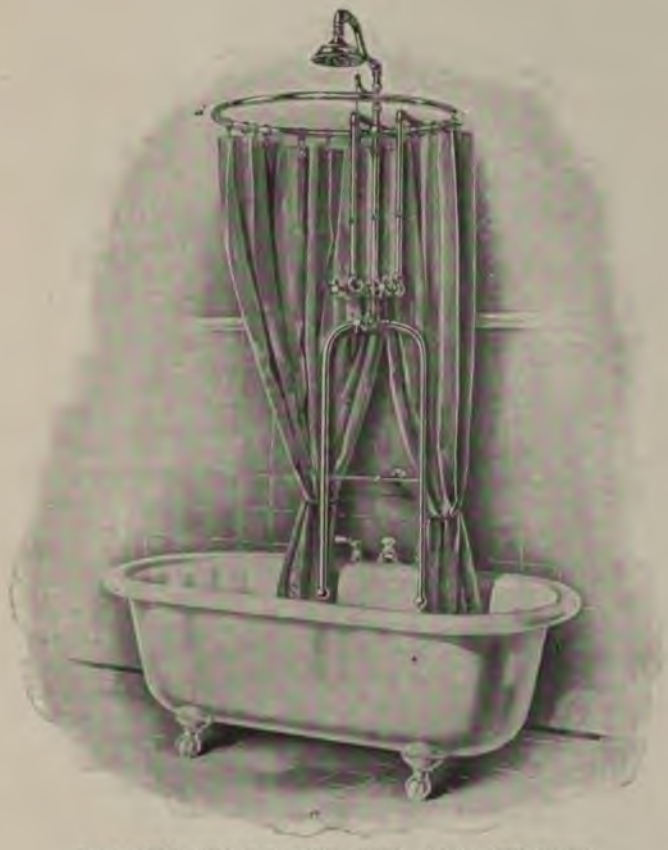
The lavatory in the bathroom (Fig. 16) is also fitted with nickel-plated Fuller corks, and nickel-plated trap to wall.

The **bathtub** is a five-foot tub of the type shown in Fig. 17.

The **closet** is of the low-tank type illustrated in Fig. 18.

Having looked over the fixtures and noted the roughing-in measurements, we shall now start on the vertical pipe work.

Vertical Pipe Work. Fig. 19 is an elevation of the **sink and wash-tray stack**, and we shall start to install this at once. Into the bend in the drain-pipe that is looking up, we first calk a 2-inch Y; and in the outlet of this Y we calk a 2-inch cleanout plug with brass cover and square head, for the purpose of clearing the pipe at any time a stoppage may occur. Continuing to the basement ceiling, we place a 2-inch Y for the sink waste. We shall probably have to use an offset here—that is, change direction and carry the piping along to where it will be in position



COMBINATION BATH TUB AND SHOWER.

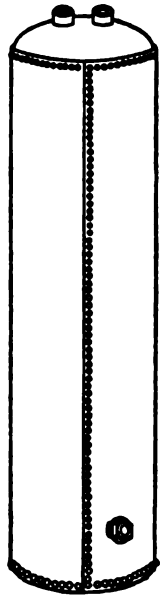


Fig. 12. Range Boiler.

Fig. 13. Stand for Range Boiler.

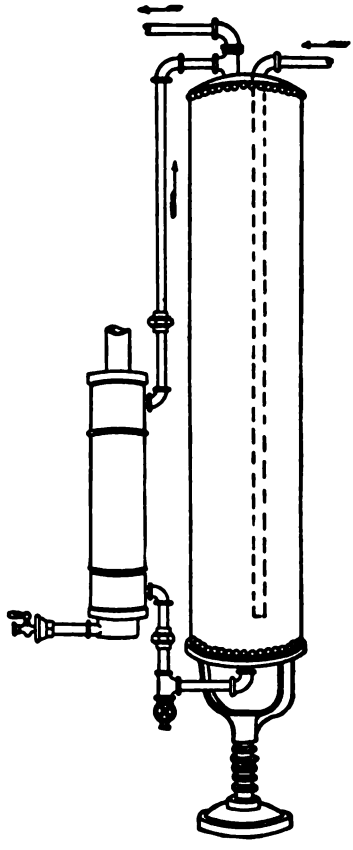


Fig. 14. Range Boiler Connected to Gas Heater.

to pass up directly through the first floor partition. Then, continuing upwards to a point about five feet above the first floor, we will place

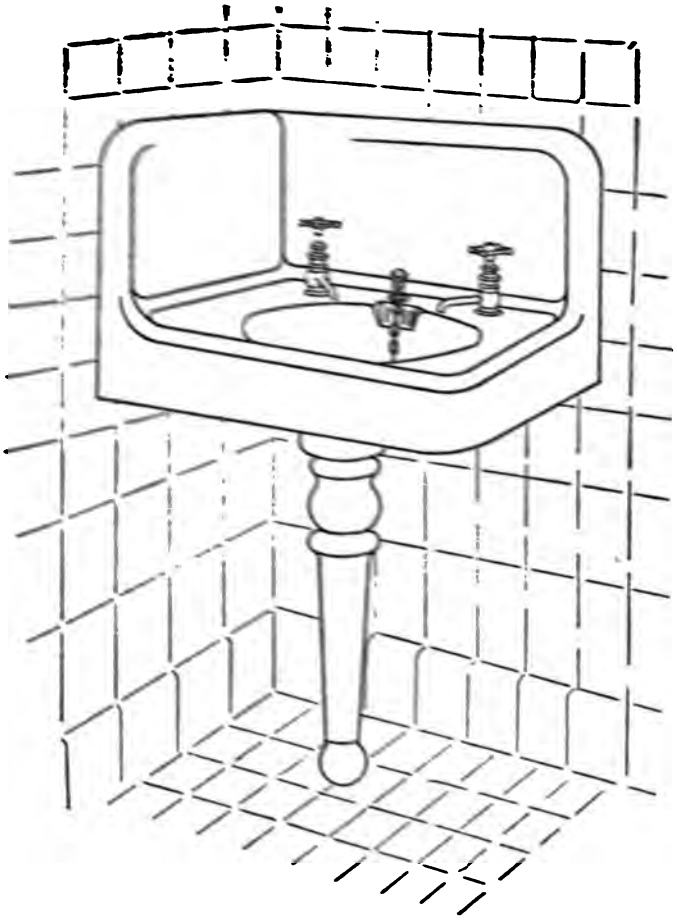


Fig. 15. Lavatory on First Floor.

a 2-inch tapped tee, for the vents from the kitchen sink and the wash trays; and then continue on up to and through the roof, enlarging

the pipe to four inches just below the roof, and placing a **roof-flashing** at the roof.

There are a number of different styles of

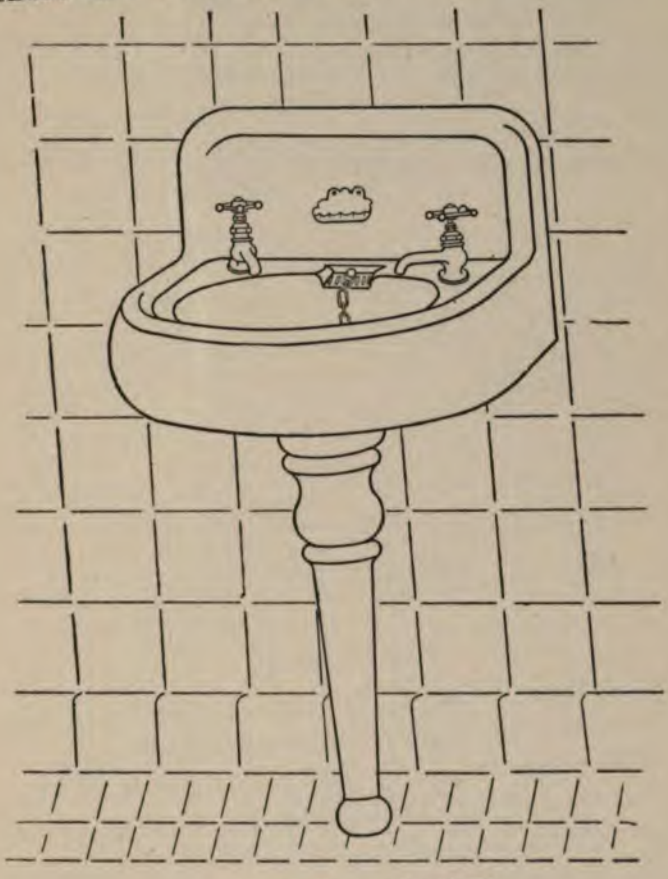


Fig. 16. Bathroom Lavatory.

roof-flashings, any one of which may be used, provided it will prevent the water from leaking through and provided it has good wearing qualities. By enlarging the pipe to four inches where

it goes through the roof, the danger of the pipe becoming closed with hoar frost is avoided. This same precaution applies to any soil or vent stack carried through the roof.

The next step will be to get in the **waste and vent pipes.** For the sink waste we shall require a 2x1½-inch brass ferrule, and about two feet of 1½-inch lead pipe. After wiping the lead to the ferrule, we calk same into the Y

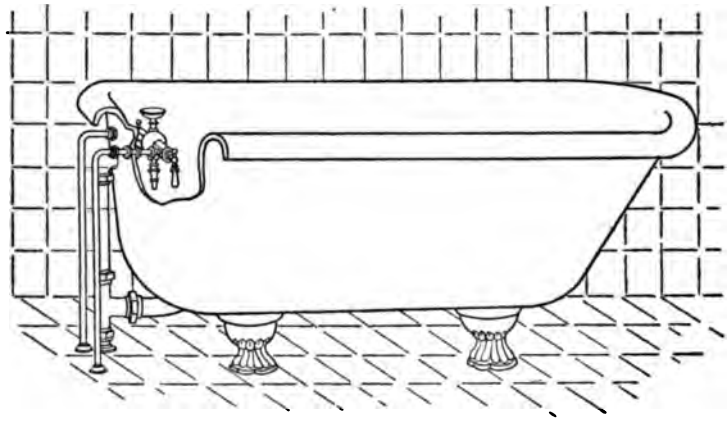


Fig. 17. Bathtub.

left for that purpose, after bending the lead pipe to the proper place to receive the sink trap.

Into the tapped tee which was left for the vents, we screw a 2x1½x1½ tee with nipple of right length, and drop out of the side opening to the basement for the wash trays, and out of the end opening to the sink. Here we shall need for the sink, and also for the trays, a 1½-inch female soldering nipple, and about 15 inches of 1½-inch lead pipe. After wiping the necessary

joints, we screw the pieces onto the pipe, after bending the same to the proper angle. Then, closing the ends so that the job can be tested,

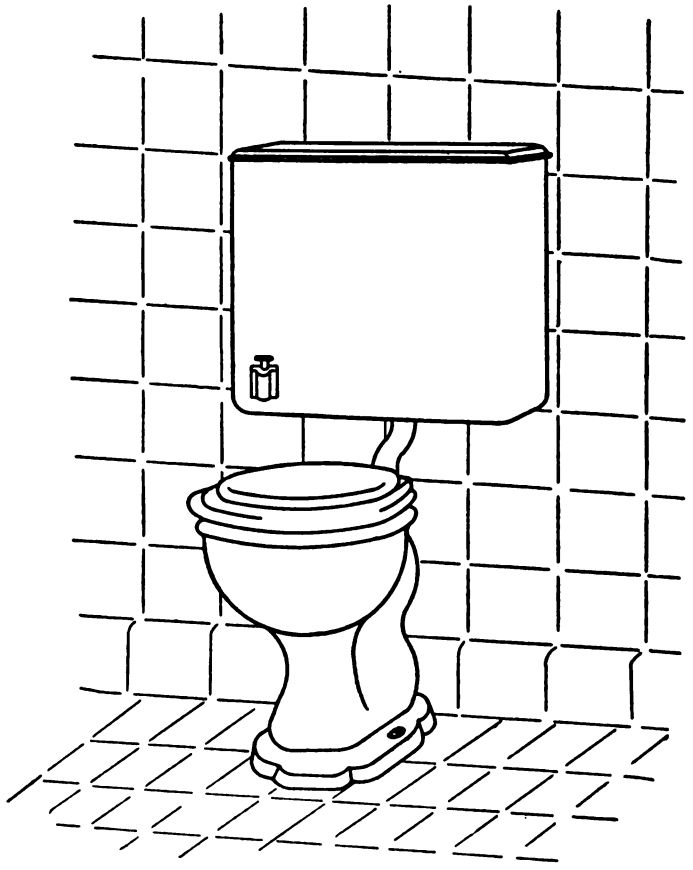


Fig. 18. Low-Tank Type of Water-Closet.

we are through with this stack until time for setting the fixtures.

It will be seen that when we set these fixtures, it will be necessary to wipe a joint be-

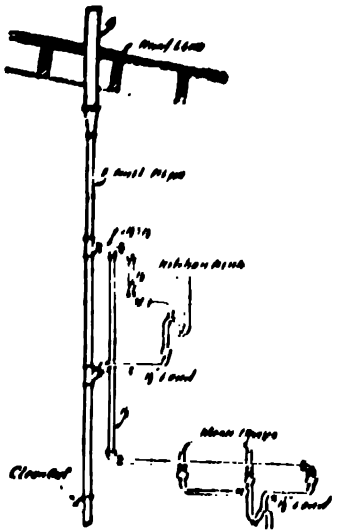


Fig. 19. Sink and Wash-Tray Stack.

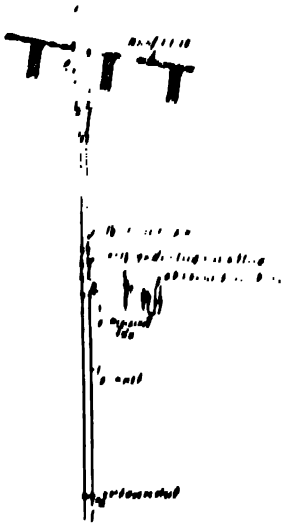


Fig. 20. Stack Elevation for First-Floor Lavatory.

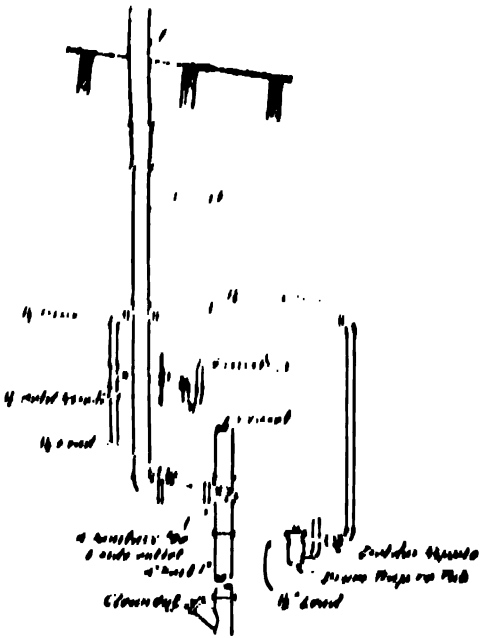


Fig. 21. Stack Elevation for Bathroom.

tween the vent pipe now in, and the vent pipe from the traps, and this connection will leave plenty of "spring" in the piping for expansion and contraction. In some localities the connection between the vents in the wall and the trap vents is made by means of **slip joints,** with a rubber gasket to make the joint tight and allow

Fig. 22. Slip-Joint Nut.

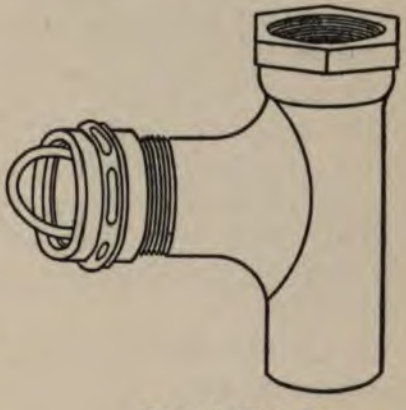


Fig. 23. Vent Tee.

for expansion and contraction. Various authorities differ on this subject, so that we shall not argue over this point, but will take up the work on the wash tray waste, which will require to be of the same style as the waste for the sink, and the end brought through the basement floor for future connection.

In some cases, a slip-joint nut (Fig. 22) is used.

Fig. 23 shows a type of vent tee that is extensively employed. This can be obtained with both ends intended for connection to iron pipe,

instead of the form shown, which is for lead waste and iron vent pipes. The part that receives the pipe from the trap has a long, threaded shank, which can be cut off to suit the job it is being used on; and this is a very good feature. See Fig. 23.

We shall now rough-in the stack for the first-floor lavatory. We first calk-in a Y with clean-out, as we did on the sink stack, and continue to basement ceiling, where we may have, as before, to use an offset to get back into the partition. At the proper height, we place a tapped tee, 2x2x1¼ inches, with a nipple in the 1¼-inch opening which will extend ½-inch through the plaster. This will allow the use of a slip-joint nut (Fig. 22) when we come to set up the lavatory.

In the top of this tee, we calk a 2x1½-inch **reducing coupling**, and extend up to a point just below the roof with 1½-inch iron pipe. At this point we screw on a 2x1½-inch coupling to calk into a 2x4-inch **increaser**, and use a short piece of 4-inch soil pipe to extend through the roof, with necessary roof-flashing.

This manner of roughing-in is termed **continuous venting**. It is preferable to venting on the sink and wash trays, since, with this style, there is not the chance for the vent pipe to choke up, which is apt to occur with the sink style of venting.

The vent work on this job will be done with black iron pipe and cast-iron fittings. Gal-

vanized pipe and fittings are sometimes used; sometimes black pipe and galvanized fittings; and sometimes again, galvanized pipe and black cast-iron fittings. In some cases, black pipe coated inside with asphaltum and having recessed drainage fittings are used. In any case, provision should be made for cleaning the vent pipes at times when needed. When a vent is taken from the top or **crown** of a trap, grease will accumulate in the vent pipe, and in time will choke it up entirely; and this is where "continuous" venting has the advantage.

The question as to what kind of material shall enter into the roughing-in of the job will be largely governed by local rulings where there is an Inspector, and the work will require inspection and testing before being covered up. Whether an inspection is necessary or not, all work should be tested before being covered up, and this will be taken up later on and fully described.

We shall now proceed to rough-in the stack for the bathroom. We first calk-in a cleanout plug into a Y, the same as for the other two stacks, and then continue up to the bathroom. Here we shall require a **sanitary tee** with a 2-inch opening in the side to receive the bath waste. We run a 4x2-inch Y in the side opening of the tee, for the lavatory waste. Continuing over to the partition, and extending upwards, we insert two tapped tees for the bath and lavatory vents, and then continue up to a point just

below the roof, where we enlarge the pipe to 5 inches and extend through the roof, with the necessary roof-flashing.

All the soil-pipe in the stacks may be "Extra Heavy" and the vents "Standard" pipe; or all may be "Standard." The specifications usually cover this point.

In the top of the 4-inch sanitary tee, we calk a combination lead ferrule, as shown in Fig. 24, and this will receive the discharge from the water-closet. Fig. 20 shows the stack elevation for the first-floor lavatory.

Fig. 21 shows the stack elevation for the bathroom. Ordinarily the closet opening would be in the side of the 4-inch sanitary tee; but in this case the opening will be in the top, owing to the fact that the first-floor partition is not directly under the bathroom partition, and requires an offsetting of the pipe-work between the ceiling and the floor. In the side opening of the closet tee, we shall connect the bath waste,

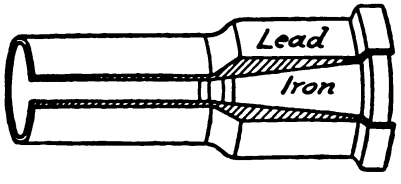


Fig. 24. Ferrule for Connecting Bath Waste to Closet Tee.

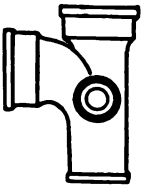


Fig. 25. Closet Tee.

which will require a 2-inch ferrule like that shown in Fig. 24 or in Fig. 26, some 1½-inch lead waste-pipe, a 4x8-inch **drum trap** (Fig. 27)

for the waste-pipe, a short piece of 1½-inch lead pipe, and a 1½-inch brass solder nipple (Fig. 28). The waste from the tub will branch into the drum trap at a point near the bottom; and the outlet to the soil-pipe will be taken out at a point near the top, but just below the vent branch.

The wiping on the bath waste can be done before setting the same in place, with the excep-

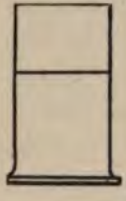


Fig. 26. Straight Brass Ferrule.

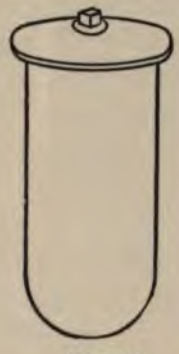


Fig .27. Drum Trap Used on Bath Waste.

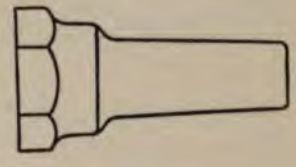


Fig. 28. Solder Nipple Used on Vent Work.

tion of the joint where the solder nipple (Fig. 28) screws onto the vent-pipe already roughed-in, and this can be wiped after the work is set in place. The screw top on the bath trap makes it easily accessible for cleaning purposes.

In the side opening of the 4x2-inch Y which is to run into the closet tee, we shall place a 2x1¼x10-inch lead ferrule (Fig. 24), which will require a wiped joint to connect it to the lead vent- and waste-pipe which is already roughed-in.

Fig. 25 shows the closet tee used on this installation, and less the side opening, this is the fitting ordinarily used.

Fig. 26 shows a straight brass ferrule; and Fig. 29 shows a tapered brass ferrule, reducing down to the size of the waste-pipe used.

Fig. 28 shows the solder nipple used on the vent work, and this is made with either male or female threading.

Fig. 27 shows the drum trap used on the bath waste. The top, being a trifle larger than the body of the trap, will cover up the hole in the floor, and make a neat finish.

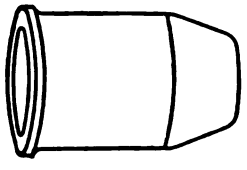


Fig. 29. Tapered Brass Ferrule.

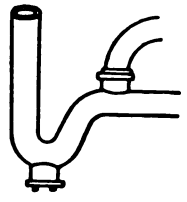


Fig. 30. A Style of Trap Often Used on Bathtubs.

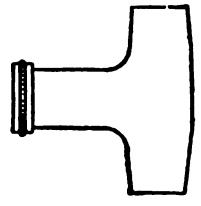


Fig. 31. Tee for Continuous Venting with Lead Waste and Vent Pipes.

Fig. 30 shows another style of trap that is used extensively on bathtubs.

Fig. 31 shows another form of tee that can be used for the continuous style of venting where lead is used for both waste and vent pipes.

Fig. 32 shows a new method of joining the closet to the soil system, to be used instead of the putty joint that has commonly been used. This makes a very sanitary job, and insures a

tight joint at this connection, which is by no means certain when putty is used. The brass flange is slipped over the 4-inch lead pipe extending through the floor for the closet connec-

Fig. 32. Graphite Gasket Closet Connection to Soil System.

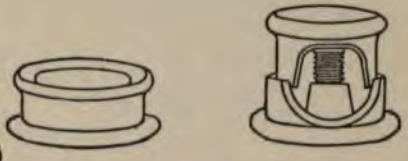


Fig. 33. Device for Steadying Bathtub on Uneven Floor.

Fig. 34. Clean-Out Plug.

Fig. 35. Type of Ferrule for Waste Pipes.
Small joint is poured.

tion; and then the pipe is sawed off at the proper distance to allow it to be flanged over into the brass floor-flange and then soldered. The graphite gasket is next placed in position, and the closet is ready to be screwed in place.

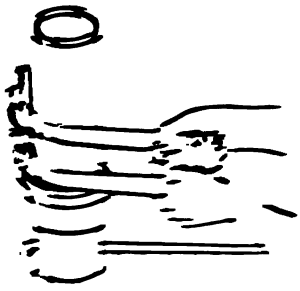


Fig. 38. [illegible]

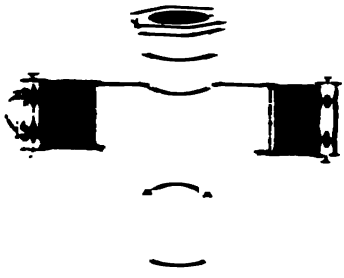


Fig. 37. [illegible]

Fig. 39. Roof Flashing.

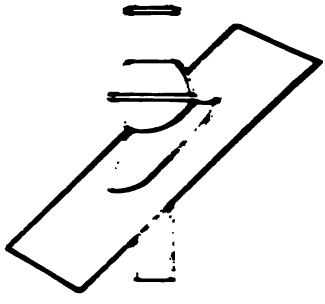


Fig. 40. Roof Flashing.

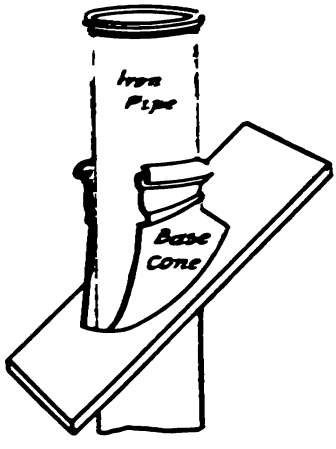


Fig. 39. Roof Flashing.

Fig. 41. Increaser.

In many instances, when you come to set your tub, you will find that the tub will not sit evenly, but has a rocking motion due to the unevenness of the floor. The device shown in Fig. 33 will be found very useful to remedy this trouble, and is inexpensive.

Fig. 42. Increaser.

Fig. 43. Increaser Tapped for Screw Pipe.

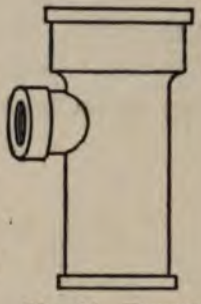


Fig. 44. Tapped Tee.

Fig. 34 shows the clean out plug which is placed at the foot of the different stacks for cleaning purposes. This has an iron body, and a brass screw; the latter is easily removed should occasion require it.

Fig. 35 shows another type of ferrule for waste-pipes. It is used by inserting the ferrule into the lead pipe, and pouring the small joint as shown.

There will be times when soil-pipe joints will be encountered in corners where it will be a hard matter to get at them to calk them properly with the ordinary tools. In this case, some of the tools shown in Fig. 36 will be found very useful.

Fig. 37 shows a waste and vent fitting that

can be used where two fixtures are set back to back.

Figs. 38, 39, and 40, show various styles of roof-flashings.

Figs. 41 and 42 show various styles of increasers, which are used at a point just below the roof. They can be obtained either to calk-in as shown, or with the bottom end tapped for iron pipe to screw in. An increaser tapped for screw-pipe is shown in Fig. 43.

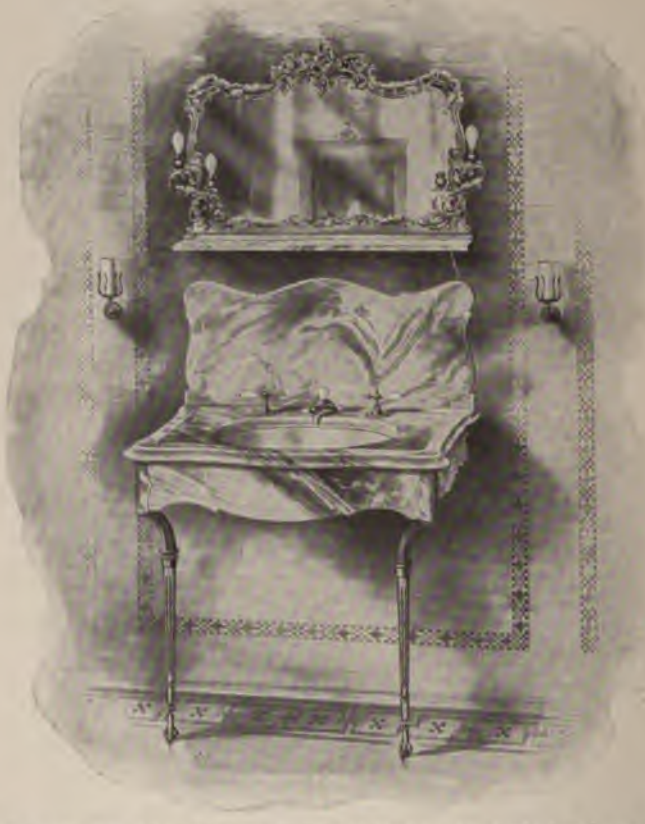
Fig. 45. Brass Bath Trap for Wrought-Iron Waste Work.

Fig. 44 shows one style of tapped tee.

Fig. 45 shows a brass bath trap that is used where the waste work is all wrought iron—or, as it is sometimes called, the "Durham" system.

Water-Service Pipes. We shall now take up the water supplies to the various fixtures.

The main in the street is usually tapped by the local Water Company, and either the connecting pipe is run to the curb line by the Company, or else the plumber takes it at the point of connection. The kind of piping is governed by local rulings. In some sections of the country it is customary to run lead pipe to the curb, and



ORNAMENTAL TYPE OF LAVATORY, BRAZILIAN AGATE.

then either lead or iron on into the building. Other places require only a short section of lead pipe at the main, usually about 18 inches in length; and from this point on into the building the pipe may be iron.

In any case, iron pipe should never be connected directly to the **corporation cock,** as the cock that is screwed into the water main is termed, on account of the rigid connection being liable to breakage from settling either of the main or of the earth over the service. For a similar reason the service into the building should never be laid in the same ditch with the sewer line, unless a shelf of earth is left alongside the sewer ditch, on which the water service can be laid, and which will insure a good foundation for it. Many a plumber has had to dig up the service after it has been in but a short time, to repair a leak in it caused through settling of the dirt.

The service should be laid below the frost line, and carried as directly as possible to the building. Where the service pipe enters the building, it should be provided with a good, serviceable **stop and waste cock,** placed at a point easily reached by the occupants of the building in case the water should require shutting off at any time on account of leaks, bursting of pipes, etc.

As the job we are installing is what is termed a "city water" job, we shall proceed to install the piping. It is understood that this is to be

put in place before the plastering is done or the bathroom floor is laid.

We start the cold-water line at the front wall where the service enters; and rising to the ceiling, we run directly to the bathroom riser, where we place a stop and waste cock so that the bathroom can be shut off independently of the balance of the system; in making this run, we put in tees at intervals for the connections for the other fixtures. The bathroom line is carried up to underneath the floor of the bathroom, where it branches to the tub, closet, and lavatory. The nipples of these branches are left extending through the floor at the proper places, being capped for testing purposes and to prevent dirt getting into the pipe.

We shall now extend the first-floor lavatory supply to the proper point, placing a stop and waste cock on this line also.

Next we shall extend the branch that supplies the laundry tubs, sink, and hot-water boiler, placing stops on the wash-tray and sink lines, but placing the stop for the range boiler at the top of the boiler. This will cut off the entire hot-water supply for the house; and separate stops can be placed on the various hot-water lines to the fixtures, if desired. The hot water for the bathroom can be either extended to the ceiling and carried across to the bathroom, or it can be taken to the cellar and carried up alongside the cold-water line. The hot lines, after leaving the boiler, can be run about the same as

the cold-water supplies; but on both lines there must be a definite place to which the pipes will drain in case it is desired to empty the entire system of water.

In connecting up the range boiler with the cold supply, a piece of pipe usually extending to within six inches of the bottom of the boiler—known as a **boiler tube**—should be screwed into the boiler coupling to which the cold-water supply is connected, for the purpose of carrying the cold water down nearly to the bottom of the boiler. The object of this is to avoid chilling the hot water, which leaves the boiler by a pipe at the top alongside the cold-water inlet pipe. This cold-water pipe should always have a small hole drilled in it at a point about one inch below the top of the boiler, to prevent the possibility of the water being siphoned out of the boiler, which might occur in case the supply were shut off for any reason. This vent-hole in the cold inlet pipe should be about one-eighth inch in size, and should always be turned away from the hot supply, or it will throw a spray of cold water directly across the hot water leaving the boiler; and it may puzzle you for a while to find out why a job that is to all outward appearance piped correctly will nevertheless not give a good supply of hot water.

In some cases, it is required that the job shall be supplied with soft water. This calls for the use of a **water lift**, and the soft water can be either pumped to an attic tank, or pumped di-

rectly into the system. There are a number of water lifts or motors on the market, operated by either electricity or by water power. In the electrically operated lift, the necessary wiring will be installed, and the soft water end will be connected by a suction pipe to the cistern, and a discharge pipe to the attic tank or directly to the system of piping through the building. In the case of a lift operated by water power, the cold city water will be connected at the opening marked for it on the lift, and the waste water can be discharged to the sewer or run to the kitchen sink (if an attic tank is used), in which case the lift will pump water whenever cold water is drawn at the sink; the discharge and suction on the soft water end will be connected up as before described.

Where the soft water is discharged directly into the piping it is necessary to place a **compression tank** in the discharge line. This is usually a 30-gallon range boiler, which acts as a cushion for the pump or lift to work against, and insures a steady flow at the faucets when water is drawn. If such a tank were not installed, the water would come in a sputtering stream as the lift delivered it into the pipe system.

In some cases where an attic tank is used for the storage of soft water, a **ball-cock**, similar to the one used for regulating the supply to the water-closet flush-tank is placed on the soft-water supply to the tank, being set to limit the

supply to a certain height of water in the tank. When any water is drawn from the tank, the lift will replace it, and the supply then be shut off by the action of the ball-cock.

Refrigerator wastes should never be connected directly to any sewer or drain-pipe, but should discharge into a sink indirectly, as per Fig. 46; or into soil-pipe, as per Fig. 47. The use to which the refrigerator is put demands that unusual care be taken in disposing of the waste water. The piping should be provided

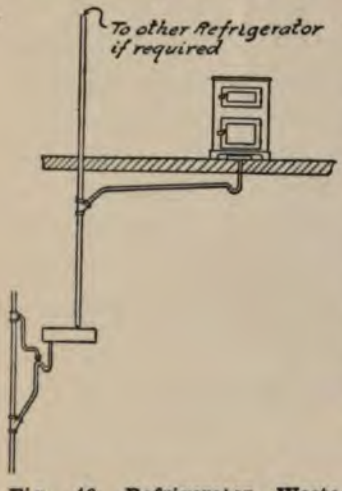


Fig. 46. Refrigerator Waste Connection to Sink.

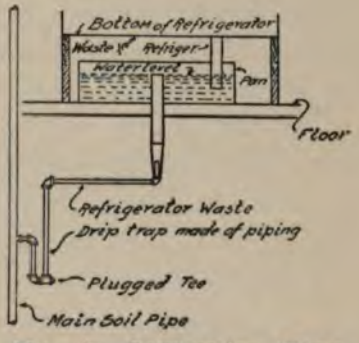


Fig. 47. Refrigerator Waste Connection to Soil-Pipe.

with cleanouts wherever there is a possibility of a stoppage occurring from the sawdust, etc., used in packing the ice; and the pipe should be run in such a manner that it can be readily taken down and cleaned if a stoppage occurs which cannot be cleared from the cleanouts. It is not

usually necessary to vent refrigerator traps, since the water does not enter the piping, as it does from other fixtures, in a large volume, but only as the ice melts, and there is little possibility of any siphonage occurring.

Waste pipes from refrigerators should be galvanized iron, with ends well reamed. The trap used at the soil-pipe in Fig. 47 may be made out of pipe and fittings. The end of the waste pipe from the refrigerator extends down into the pan (Fig. 47); and the waste to sewer connected toward the top of the pan will leave a place for the dirty matter from the ice to collect, and this can be removed frequently, being thus prevented from entering the waste pipe. By making the trap seal at the soil-pipe about 6 to 8 inches in depth, there will be little danger of this trap being siphoned from the discharge of fixtures on the line above; and even if this did occur, the dripping from the ice would soon seal the trap again.

TESTING THE PLUMBING

After a job has been roughed-in, and before being covered up, it should be thoroughly tested, to obviate the necessity for any tearing-up of floors or removal of plaster in order to locate and repair leaks that may show up after the fixtures are set.

Water Test. The water test is usually applied on new work, and is one of the severest tests that can be adopted. Any defective ma-

terial or leaks in joints will be readily detected when the system is filled with water. The mode of applying the water test is to close up all openings in the soil, waste, and vent pipes, either by

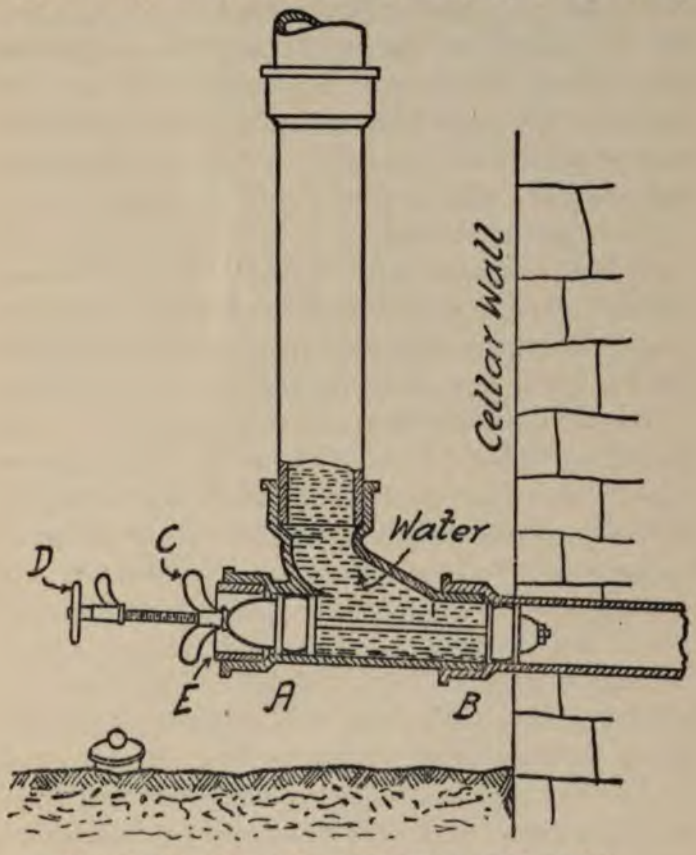


Fig. 48. Illustrating Use of Test Plug in Water Test.

soldering the ends shut, if lead is used; by plugs or caps, if iron pipe is used; or by test plugs.

Fig. 48 shows one style of test plug. These plugs are made in different forms to suit all the

uses for which they may be called upon in testing a job. The rubber ring expands against the sides of the pipe when the handle is screwed down, and it will stand considerable pressure before blowing out—more pressure, in fact, than will be placed on the piping system during the test. The water supply for testing may be connected to the end of the test plug where capped, with a stop-cock to shut off when necessary; and then the system is ready for filling.

The filling should be done slowly, and any leaks found should be immediately fixed. Where a leak occurs in a lead joint which only requires a little more calking, the water may be shut off until this is done: but if a split pipe or fitting is found, it should immediately be replaced. It is better to fill from the bottom of the stack, since filling from the top is apt to allow water to run down the piping, and, having the appearance of a leak, makes the testing a more difficult job than is actually necessary. The stacks may be tested in sections as the job progresses, by leaving out a joint of pipe and inserting same for the final test. This may be found necessary owing to the plasterers being in a hurry to get their work done: and after inserting the sections that were left out, it is a simple matter to test them on the final filling.

A careful inspection of the material as it is being put in place, will save much trouble at times, as it is an easy matter to detect cracked pipings or fittings by tapping same with a ham-

mer. The difference in sound between good and defective material is easily detected by the ear after a little practice.

Smoke Test. The smoke test is another test that can be applied to roughed-in new work. It is used most frequently, however, in testing old work, or in testing new work after the fixtures have been set. The manner of applying a smoke test is to close all openings, the same as for the water test, and also the openings at the roof. The testing machine, which is made especially for this purpose, is then connected to the piping system, and the smoke turned into the pipes. Oily waste or rags are placed in the machine and lighted, thus generating a heavy smoke which will entirely fill the pipes, and escape through any leaks that may exist—which are thereby easily detected. The smoke test is preferred by many, as it is cleaner than the water test, should any leaks develop, and there is no wetting down of the building.

Peppermint Test. The peppermint test is applied by putting about two ounces of oil of peppermint into the system at the roof, after all openings have been closed as with the other tests, and pouring about a gallon of hot water into the piping, immediately closing the opening with a plug kept at hand for the purpose. The fumes of the peppermint are supposed to travel throughout the system of piping, and to penetrate any existing leaks, the presence of which can then be detected from the characteristic

smell. There being no pressure applied in this test, there is a possibility of the odor not escaping through very small leaks; and this test, therefore, is not so reliable as the water or smoke tests.

The person who puts the peppermint in the piping should not try to look for leaks, as he will carry the odor around with him through the building, and is apt to imagine that he smells leaks where in reality they do not exist.

In the water test, the piping at the bottom of the system will receive the heaviest pressure; and in tall buildings, this pressure may be heavy enough to burst the pipes. It may be policy, in such cases, to test the job in sections, as spoken of before. The pressure that will be exerted on the stacks at any given point, can be easily determined by multiplying the head, in feet, by the decimal .434—which will give the pressure in pounds per square inch at that point. Every foot in height of a column of water exerts a pressure per square inch of .434 pounds; and in a tall building, it will readily be seen, this pressure will amount to considerable at the foot of the stack.

Local rulings generally prescribe the form of test to be applied to plumbing installations. Many plumbers, where there are no local rulings requiring or regulating tests, test all their work for their own satisfaction, and are then in a position to guarantee absolutely with some degree of satisfaction, all the work they install.

The added cost for testing does not amount to a very large item; and it gives the plumber the advantage of an added prestige when it becomes known to his customers—both the customers he already has, and prospective ones—that any job he does must be right to his own satisfaction before he is ready to turn it over to his customers; and this will soon increase his list of clients. There is only one way to do work, and that is to **do it right;** and this fact soon becomes known, and to your credit.

HOT-WATER SUPPLY

There are various ways of heating the water for domestic and other uses. We shall first take up the manner of heating by **range boilers** and **coils** or **water-backs,** passing on to **automatic** and **instantaneous heaters.**

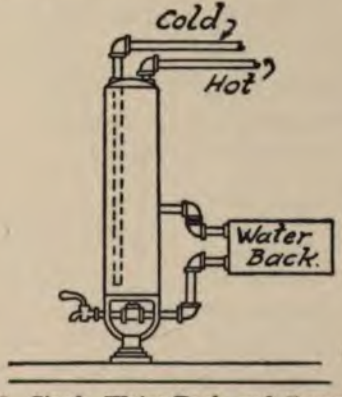


Fig. 49. Single Water-Back and Connections.

Fig. 49 shows the common method of connecting a range boiler to a pipe coil or a cast-

iron water-back. The sketch is self-explanatory. If lead pipe is used, care must be taken that there will be no pockets for the air to collect in, as this will seriously interfere with the working of the job. Lead pipe does not give as good satisfaction for the hot-water pipe from the water-back to the boiler, as does the use of brass or iron, since the expansion and contraction due to alternate heating and cooling have a tendency to stretch the lead pipe, and in time will start a leak. Galvanized-iron or brass piping is slowly

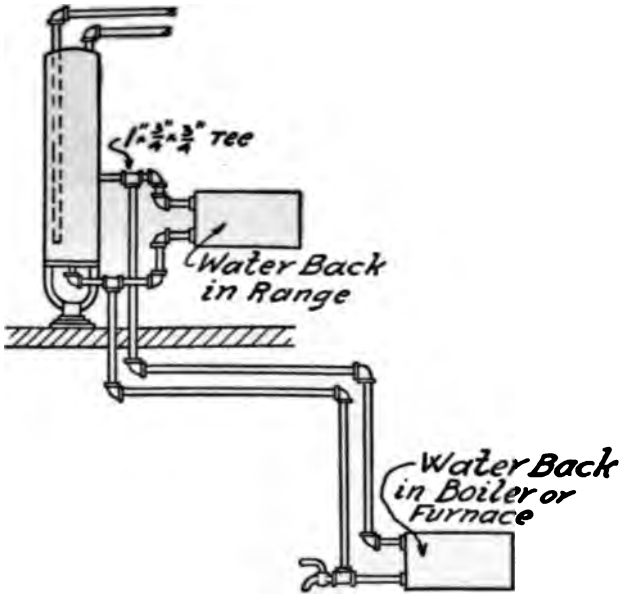


Fig. 50. Connections to Water-Back and Furnace.

replacing the use of lead pipe, and in some jobs there is no lead pipe used whatever. Fig. 49 shows a connection to one water-back only.

Fig. 50 shows the same form of connection for the water-back on the first floor, but also shows a connection to the furnace or boiler in the basement. The **sediment cock**, it will be noted, is placed at the **low point** in the basement, whereas, on the first floor, it was placed under the range boiler. Any number of water-backs can be connected to a single boiler, if due care is taken in making the connections, so that the hot-water currents will not buck against each other, and reverse the water travel or cause hammering.

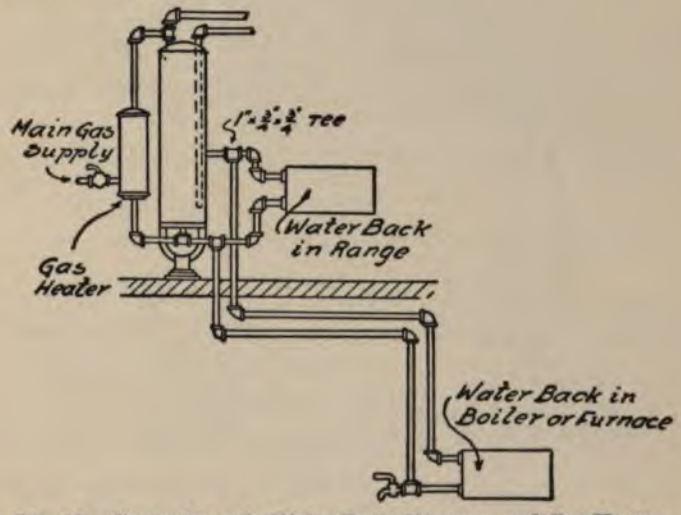


Fig. 51. Connections to Water-Back, Furnace, and Gas Heater.

Fig. 51 illustrates about the same thing as Fig. 50, but shows a **gas-heater** also connected. This heater, if desired—as, for example, in hot weather in summer-time—will work independently of the other means of heating the water

in the boiler; or they may all be working at once, without interfering with the action of one another. In some cases the gas-heater is connected to the boiler alone, and is the only means of heating the water. This very often occurs in

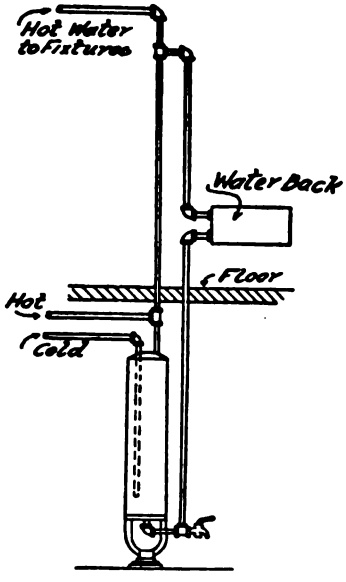


Fig. 52. Type of Range-Boiler Installation Rarely Used.

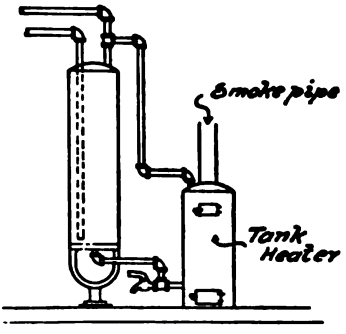


Fig. 53. Tank-Heater Installation.

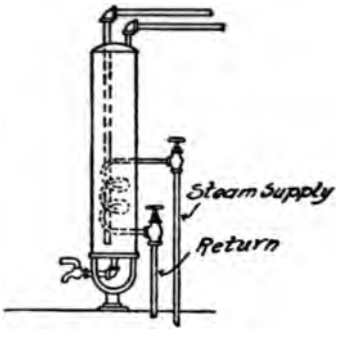


Fig. 54. Vertical Range Boiler with Steam Coils.

apartment houses or "flat buildings," where the structure is heated by steam, and where gas stoves are used for cooking; or the gas stove may have a water-back connected to the range boiler.

Fig. 52 shows a type of range-boiler installation which is very rarely used and is not very successful in operation, as the circulation is apt to be sluggish. It will work as shown in the sketch; and the higher the loop extends above the top of the boiler, the faster will be the circulation; but the use of this type of installation should, if possible, be avoided. If, however, this type must be used, the hot water must be taken from the top of the loop, in order to free the loop from the air which will accumulate at that point.

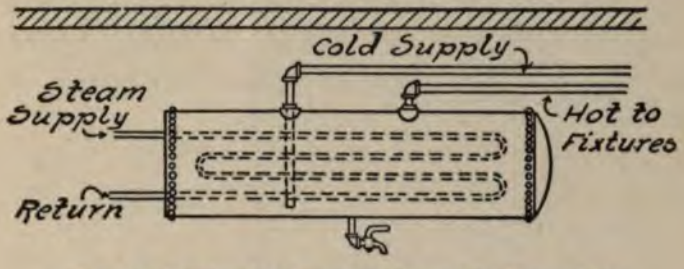


Fig. 55. Horizontal Range Boiler with Steam Coils.

Another form of hot-water heater in very frequent use is shown in Fig. 53—called a **tank heater.** Heaters of this type are constructed in various styles and sizes to meet all requirements. The sketch shows the manner of connecting to the range boiler. These heaters are used extensively where large quantities of hot water are desired, and are very satisfactory.

Figs. 54 and 55 show different types of range boilers with steam coils therein, by which the water in the boilers is indirectly heated. This is an economical method of heating water where

a building is heated by steam, and where there is exhaust steam available. By its use the cost of heating water is reduced practically to nothing.

Sizes of Coils. As any plumber may be called upon to install a boiler of this type, we shall figure out the size of steam coil necessary to raise the temperature of the water in a 30-gallon range boiler from the average temperature of the water supply, say 70 degrees, to a temperature of 160 degrees, that desired for use.

Since a gallon of water weighs 8⅓ lbs., and the boiler contains 30 gallons, it follows that $30 \times 8\frac{1}{3} = 250$ pounds, the weight of water in the boiler.

The increase in temperature desired is from 70° to 160°—a total of 90 degrees, since 160—70=90.

Since a heat unit is the amount of heat required to raise one pound of water one degree in temperature, then, in order to raise 250 lbs. 90 degrees, we shall require a total of $250 \times 90 = 22{,}500$ heat units.

The steam pressure is 2 lbs., gauge.

Temperature of the steam at this pressure is 220°.

Average temperature of water is found by adding maximum and minimum, and dividing by 2; thus, $(70+160) \div 2 = 230 \div 2 = 115°$, average temperature of water.

Average difference in temperature between steam and water is 220—115=105 degrees.

MODERN BASEMENT LAUNDRY.

It is a well-known fact that steam coils surrounded by air at a temperature of 70 degrees give off roughly about 2 heat units per degree difference in temperature per hour; but when placed in water they condense steam approximately 50 times as fast per degree difference in temperature. It is also a well-known fact that one square foot of heating surface will transmit about 100 heat units per hour per degree difference in temperature. Therefore each square foot of steam coil in the boiler water will give off $105 \times 100 = 10{,}500$ heat units per hour.

The total square feet of heating surface required will therefore be $22{,}500 \div 10{,}500 = 2.14$ square feet approximately.

Now, since it requires 2.9 feet of 1-inch pipe to equal 1 square foot of heating surface, therefore $2.9 \times 2.14 = 6$ feet 3 inches, approximately, of 1-inch pipe in the coil required for heating the 30 gallons from a cold-water temperature of 70° to a temperature of 160° with steam at 2 lbs. pressure—or about 1 square foot of heating surface in the coil to each 14 gallons of water in the boiler.

The ordinary range-boiler with a steam coil will give entire satisfaction if the steam coil is based on 1 linear foot of 1-inch pipe to each 5 gallons of water to be heated per hour, the water being heated from a temperature of 60° to one of 160°; and this is the basis on which they are constructed.

The same method of calculation can be used

for steam or water at varying temperatures, and for lesser or greater quantities of water. The ratio of 1 square foot of heating surface to each 15 gallons of water to be heated is based on iron pipe coils; and the ratio for brass or copper piping will be about 1 square foot to each 20 or 25 gallons, owing to brass or copper being a better conductor than iron.

The size of the pipe coil necessary for heating the water when coils are placed in a stove, furnace, or boiler, can be determined by allowing 2½ square inches of surface actually exposed to the fire, for each gallon of water to be heated. This would mean 75 square inches of surface for a 30-gallon boiler, or about 2 feet of ¾-inch pipe, or about 1 foot 6 inches of 1-inch pipe. This piping should have the ends well reamed of the burr that is left by the cutters when cutting off the pipe, as the burr would have a tendency to cause the coil to choke or lime up if the water should be dirty.

The above calculation is based on heating the water in the boiler in one hour. If it is desired to heat it faster, a greater amount of surface must be used, and the surface required can be readily determined from the above data.

The proper size of water-back or coil for a range boiler must be carefully determined. The use of a coil that has too much heating surface will result in considerable annoyance to the occupants of the building, from the rumbling noises that will be caused by the water boiling. This

is a very common mistake, and should be watched. On the other hand, do not make the coil too small, as it will simply have to be replaced by a larger, and here is where the plumber is apt to go to the other extreme and put in a coil too large. A careful following of the facts stated above will enable one to install the proper size at once.

Instantaneous Hot-Water Heaters. Figs. 56 and 57 show common types of instantaneous hot-water heaters. Their operation is as follows:

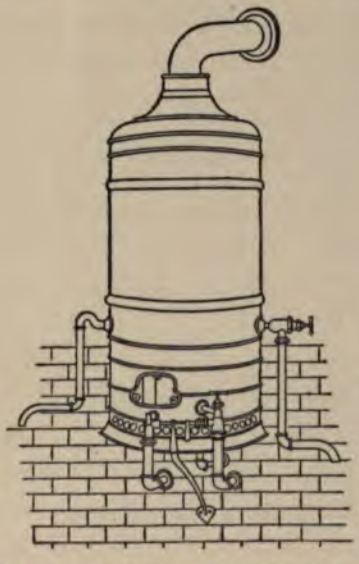


Fig. 56. Instantaneous Hot-Water Heater.

Water and gas or gasoline being connected to the heater at the proper places, the water, on being turned on, is carried to the top of the heater, where it is distributed in a thin sheet or

small streams flowing downward over a sheet-metal cylinder which forms part of the interior construction of the heater, and thus becomes warmed, after which it is carried to point desired. These heaters have the water and gas valves so constructed that it is impossible to turn on the gas without also turning on the water, and the burning of the heater is thus avoided. A vent-pipe should always be attached to the top of a heater, and carried to some convenient flue, although it is claimed for the heater shown in Fig. 57 that no flue is necessary. A drip-pipe should be attached to the drip-pan or shelf on

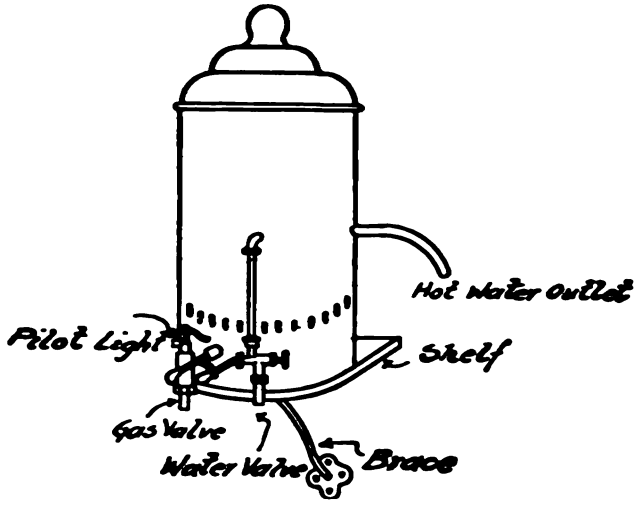


Fig. 57. Instantaneous Hot-Water Heater.

which the heater rests, to take care of the condensation which will occur at times.

This type of heater is made in sizes that will give from 1 to 9 gallons per minute, heated from

the ordinary temperature of cold water to a temperature about 110° to 120°; but is seldom used when water of a higher temperature is desired. Heaters of this type are very extensively em-

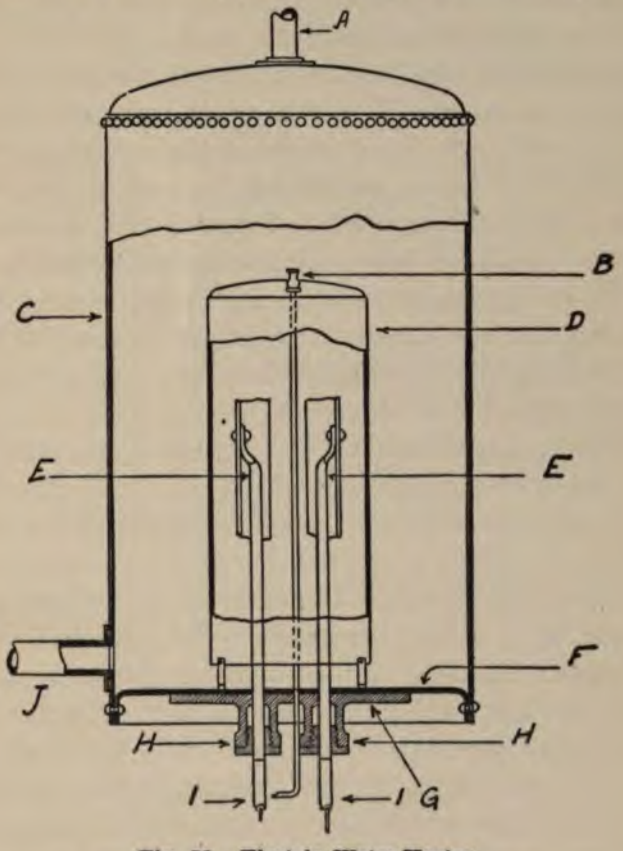


Fig. 58. Electric Water-Heater.

ployed for heating water for bathing purposes during the summer months in private houses, and give universal satisfaction. They are furnished in plain finish and also nickel-plated,

and there are a number of good makes on the market.

Fig. 56 shows an **electric water-heater.** A represents the hot-water outlet of a 1-inch pipe; B is the air and steam vent-pipe and valve; C is a 15-gallon galvanized-iron tank (cut away in part to show the steam can); D is the steam can, which is closed at the top and open at the base, and partly cut away in the figure to show the position of the electrodes; E represents the two electrodes which consist of pieces of 1-inch iron pipe, sketched here in section to show the method by which the current-supply wires are connected. F shows the concave bottom of the main tank; G is a removable plate with a water-tight gasket; H H are stuffing-boxes; I I are extra-insulated rubber wires supplying current to the electrodes; and J is the 1-inch pipe through which cold water is supplied to the tank.

The construction is based on the principle of a water rheostat operated under an inverted tank or can, all being enclosed in an outer tank, the water in which is either under pressure or otherwise as may be desired. The inner or inverted can contains electrodes, marked E E in the diagram, which are separated a distance of an inch and one-quarter and on which is maintained a pressure of 500 volts in 60-cycle alternating current. Obviously, any steam formed by the heating of the water will rise within this inner can; and, as its pressure increases, it drives

the water therein downwards, hence off the electrodes, thus automatically controlling the current consumption and keeping the can filled nearly full of steam, which in turn maintains the temperature of the water in the outer tank at a point near boiling.

This heater is not on the market. One of this type, however, has been in operation for a little over three years, and has given good satisfaction. It is interesting to note that while its maximum consumption of energy is approximately five kilowatts when both tanks are filled with cold water, this consumption decreases gradually as the temperature of the water rises and its position in the inner tank lowers, until it reaches a minimum of three-tenths of a kilowatt. The capacity of the outer tank is 15 gallons, and it is but partially protected from the cold air. At A is located a small valve by means of which trapped air may be let out from the inner can, or, if desired, steam may be blown from it in order to hasten the heating of the water in the outer tank if an extra amount of hot water is wanted quickly. The steam can and electrode are mounted on the bottom plate of the main tank, to which they are attached by cap screws.

It is desirable that the tank should be insulated, and that its inlet and outlet pipes should consist of rubber hose to prevent the grounding of the current supply. While the plumber will not be called upon to install a heater of this description, still it is well to know how water can

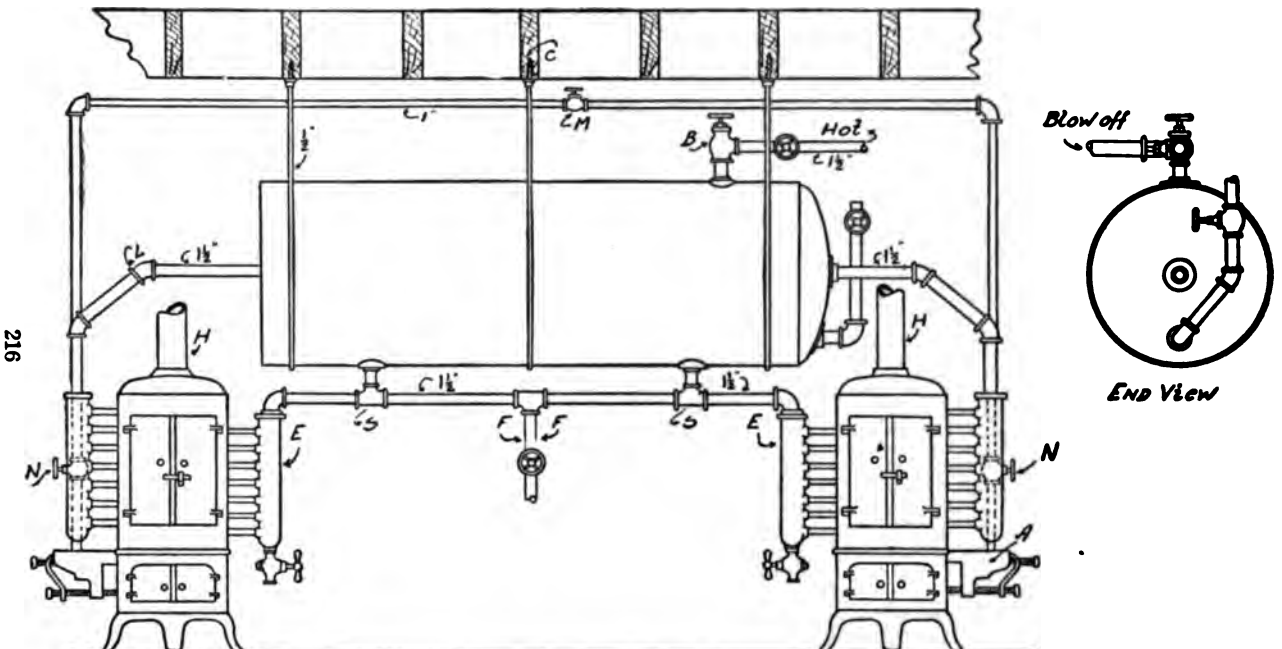


Fig. 59. Typical Automatic Water-Heater Installation—Ruud System.

be heated successfully by means of electricity. Heating water by electricity is a commercial possibility of the future, and the plumber who understands it is abreast of his calling.

Automatic Water-Heaters. These are made in a number of styles. Fig. 59 illustrates a typical installation, the type of heater shown being known as the "Ruud."

These heaters consist of a series of copper coils arranged one above the other, underneath which is a cluster of Bunsen burners. They are operated by a thermostat valve which acts as follows: When the hot-water faucet at the sink or some other fixture is opened, cold water passes over the thermostat, causing it to contract and open the gas-valve, which admits a large quantity of gas to the burners. This is ignited by a pilot light maintained by a small by-pass in the valve. This large volume of gas, burning up through the coils, instantly raises the temperature of the water to the desired heat. The temperature is regulated by the volume of gas admitted to the heater through the thermostat. As long as cold water is being drawn, gas is burning, and of course hot water flows. When the faucet is closed, the flow of water into the heater and through the thermostat ceases, causing the thermostat to heat and expand and thereby closing off the flow of gas to the heater, with the exception of the small amount required for the pilot light, which burns constantly.

This is the arrangement of a single heater for

use in private dwellings; but in public buildings, such as a hospital, where a large quantity of hot water is needed, a storage system is used. Fig. 59 shows the installation for use in a hospital or other large building requiring a large volume of hot water. Connections are shown for a circulating system of piping. A 300-gallon tank is suspended from the joists by means of ½-inch lag screws turned up into the joists as shown at C. The hangers can be made by turning ½-inch pipe into the desired shape. Left-hand threads can be cut on the ends of the pipe, and connected to the lag screws by means of right and left couplings (D). Two No. 6 Ruud heaters are used, one at each end of the boiler, and connected up with brass pipe of the sizes indicated. The return pipe I is connected to the top of the manifold E.

At first glance, this seems to be against both theory and practice; but, as each individual coil is connected separately to the manifold, with a pitch of about 3 inches from one manifold to another, it is not so much against good practice as it seems.

The water supply F is connected into a reducing fitting (S) in the manner shown, so that it will act on the injector principle, thereby inducing a more rapid circulation when water is being drawn at the fixtures. On the circulation pipe L, 45-degree fittings are used, so as to offer as little resistance to the flow of water as possible.

Gas to the heaters is supplied through the pipe M, a globe valve N, being placed on each branch supply pipe at the most convenient point.

The hot-water supply pipe is taken from the top of the boiler, a blow-off valve being placed at B. This valve is set to blow off at a few pounds above the maximum street pressure, so that if the water gets excessively hot at any time, it will not expand back into the cold-water supply for the building. There is no check-valve shown on the return circulation pipe G, and it would be advisable to place a swinging check-valve, with a light disc, at the foot of each rising line connecting into the main return line. If this is not done, cold or partially cooled water will be likely to work back up any one of the circulation risers; and, when the faucets are opened, the hot and cool water might mingle at the point of junction, so that, unless the water in the boiler is excessively hot, water only partially heated might be drawn.

The smoke-pipes HH are to be connected to a convenient flue.

A careful study of the sketch and the description will make this type of heater perfectly clear.

Other types of automatic heaters are governed by the temperature of the water. After the heaters are set—that is, after the thermostats have been set—a slight change of temperature in the water will automatically turn on the gas, which will burn until the water reaches the

temperature for which it has been set; and then the gas supply will be automatically shut off, this operation being repeated indefinitely.

Either style of heater is very satisfactory, and, after being installed requires very little attention, as all are what their name implies—automatic.

Fig. 60 shows a typical installation of hot- and cold-water supply, with cold-water supply from street mains. As there is no place for the water to expand when heated, except back into

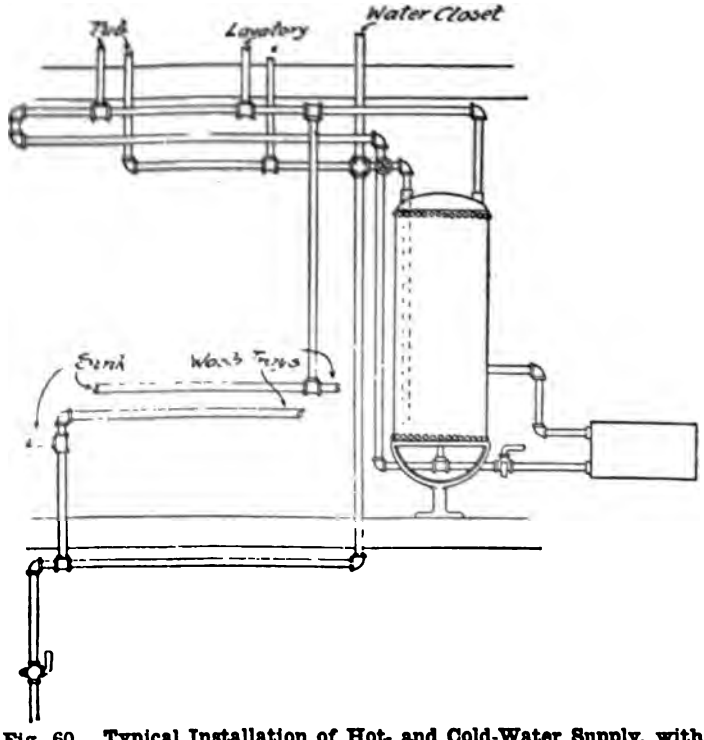


Fig. 60. Typical Installation of Hot- and Cold-Water Supply, with Cold Supply from Street Mains.

the street mains through the cold-water supply, a check-valve should not be placed on the cold-water supply pipe. Be sure and drill a ⅛-inch hole in the boiler tube about one inch from the top of the boiler, and see that the spray from this opening does not shoot across the hot-water outlet and chill the outgoing hot water. By placing a valve on the cold-water supply to the boiler, the hot water may be shut off the system for the purpose of making repairs, etc., without interfering with the cold-water system. This is the common method of piping for the average installation in residence work, where the water supply is taken from the street mains, and the water can be heated by any of the methods heretofore described. If an automatic water-heater is used, the boiler and water-back may be omitted.

Fig. 61 shows a piping system in which the fixtures, with the exception of the water-closet and sink, are supplied with soft water, these two fixtures being supplied with city water. On the riser from the water-lift, at the attic tank, is placed a ball-cock such as is used in the tank of the water-closet, which maintains an established amount of water in the tank, and, when any water is drawn off, will automatically replace the amount used. The sketch shows the fixtures supplied with cold soft water, from the riser from the lift running to the tank; and the cold-water supply to the range-boiler is taken from the tank directly. When ordinarily used,

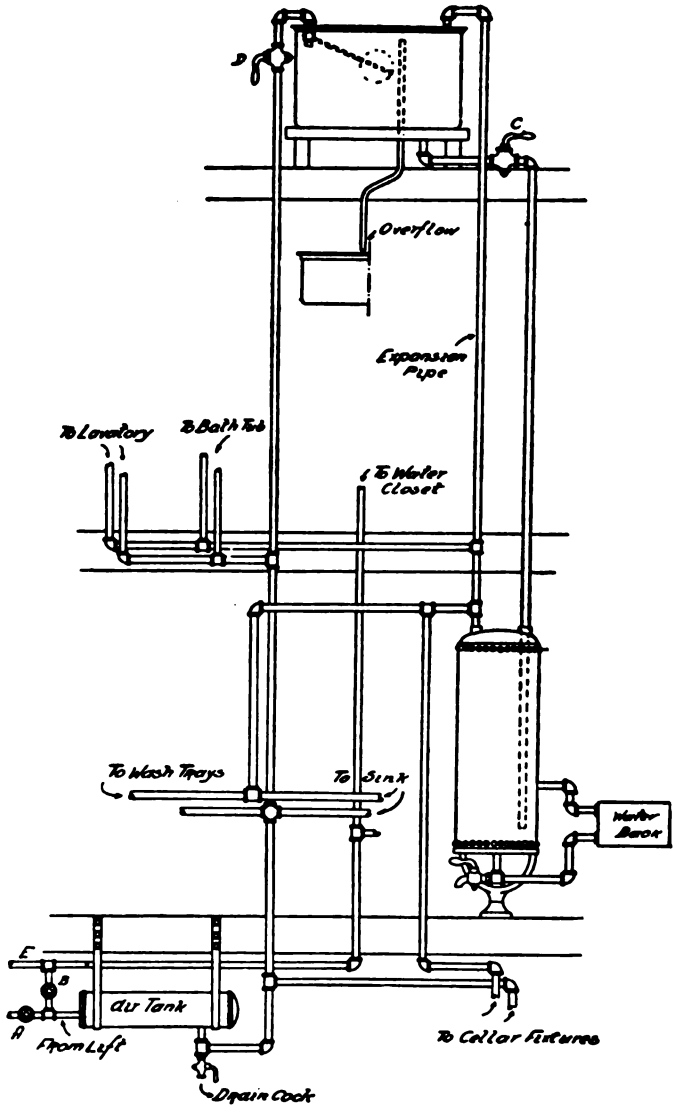


Fig. 61. Hot- and Cold-Water Supply Piping System for a Residence.

Water-closet and sink supplied directly with city water.

the valve B is closed; but in case the soft-water supply gives out, closing valve A and opening valve B will admit city water into the entire piping system. The attic tank provides a reserve supply of water in case the city water is shut off temporarily. By cross-connecting the pipes D and C, and placing a check-valve on pipe E and the cross connection, when the pressure goes off the riser pipe to the attic tank, the check-valve will allow the water from the tank to enter the piping system, and the check-valve at E will prevent the water from going out to the street mains, this operation being reversed when the city pressure comes on again.

Fig. 61 is a combination of several possible systems, and should be studied carefully, as it embodies almost everything that the plumber will be required to place in the average installations. By leaving out the attic tank, and connecting pipes D and C, the regulation closed system of soft-water supply by means of a water-lift is shown. A 30-gallon tank is suspended from the basement ceiling, on substantial hangers; and into it the discharge from the soft-water cylinder of the water-lift enters through a bent pipe which throws the incoming water to the bottom of the tank, this action having a tendency to prevent any sounds in the piping which might be caused by the action of the lift. It is good practice to place an air-chamber on the city water supply to the lift, to take up the

jar that is caused by the lift cutting off at the end of the strokes.

The cold-water supply to the fixtures is taken from the bottom of the tank, thus getting the full benefit of the compressed air which is stored in the top of the tank, and thus insuring a steady flow of water at the fixtures, which will not be obtained without the use of the tank.

Where the soft water is pumped directly to the attic tank, the city water waste from the lift can be carried to the kitchen sink; and when any city water is used at the sink, the lift will operate and discharge a certain quantity of water into the tank. A ball-cock at the attic tank should not be used if this is done.

Another method is to run a separate riser to the attic tank, and provide a ball-cock as shown. This does away with the air-tank; and in case the soft-water supply gives out, the opening of a valve in the cross-connection between the city water and the soft-water riser to the tank will allow the city water to enter the riser to the tank; and the cold water branches to the fixtures can be taken either from the riser to the tank, or from the cold-water supply to the range-boiler. The latter method is preferable, as the full benefit of the water in the tank will be obtained in the entire piping system, which would not be possible if the branches were taken from the riser to the tank.

Any one of these installations is really simpler than would seem to be the case from the

Hand-Operated Flush.

Seat-Operated Flush.

EXAMPLES OF MODERN LOW-TANK TYPE OF CLOSET.

description; and a careful study of the above will enable the reader to cope with any hot-water heating problem that is likely to arise in ordinary practice.

USEFUL TABLES, RULES, ETC.

The experience of practical plumbers has resulted in the accumulation of a great mass of useful information which has been embodied in the convenient form of ready tables, concise practical rules, etc. We now present such portions of this accumulated fund of information as will be found of greatest practical value in ordinary plumbing work.

TABLE IV

Carrying Capacity of Sewer Pipes, in Gallons per Minute, with Varying Fall in Inches per 100 Feet

Size of Pipe	Fall per 100 Feet, in Inches							
	1 in.	2 in.	3 in.	6 in.	9 in.	12 in.	24 in.	36 in.
3 inch	13	19	23	32	40	46	64	79
4 "	27	38	47	66	81	93	131	163
6 "	75	105	129	183	224	258	364	450
8 "	153	216	265	375	460	527	750	923
9 "	205	240	355	503	617	712	1,006	1,240
10 "	267	378	463	755	803	921	1,310	1,613
12 "	422	596	730	1,033	1,273	1,468	2,076	2,554
15 "	740	1,021	1,282	1,818	2,224	2,464	3,617	4,467
18 "	1,168	1,651	2,022	2,860	3,508	4,045	5,704	7,047
24 "	2,396	3,387	4,155	5,874	7,202	8,303	11,744	14,466
27 "	4,407	6,211	7,674	10,883	13,257	15,344	21,771	26,622
30 "	5,906	8,352	10,223	14,298	17,714	20,204	28,129	35,513
36 "	9,707	13,769	16,816	23,763	29,284	33,722	47,523	58,406

Capacity of Sewer Pipe. The carrying capacity, in gallons per minute, of sewer pipe laid at various grades, is shown in Table IV.

Discharge of Sewer Pipes. Table V shows

the discharge from various-sized sewer pipes laid on a grade of 1 foot in 100 feet.

Size of Sewer Pipes. Table VI shows the size of sewer pipe required to carry off the rain

TABLE V

Discharge of Sewer Pipes

Grade of 1 Foot in 100 Feet

Diameter of Pipe	Discharge Cubic Feet per Second	Discharge Gallons per Second
4 inches	0.16	1.2
6 "	0.49	3.7
8 "	1.11	8.3
9 "	1.53	11.48
10 "	2.05	15.38
12 "	3.4	25.5
15 "	6.29	47.2
18 "	10.37	77.8
20 "	13.85	103.9

TABLE VI

Size of Sewer Pipe to Carry Rain Water from Roofs

Average Conditions of Rainfall

Size of Pipe	Area of Roof When Fall in Sewer is ¼ Inch per Foot	Area of Roof When Fall in Sewer is ½ Inch per Foot
5 inch	3,700 Sq. Ft.	5,500 Sq. Ft.
6 "	5,000 " "	7,500 " "
7 "	6,900 " "	10,000 " "
8 "	9,100 " "	13,600 " "
9 "	11,600 " "	17,400 " "

TABLE VII

Dimensions and Weights of Galvanized-Iron Range Boilers

Capacity of Boiler	Size	Weight, "Standard"	Weight, "Extra Heavy"
30 gallons	12x60 inches	78 lbs.	100 lbs.
40 "	14x60 "	96 "	120 "
52 "	16x60 "	126 "	152 "
63 "	16x72 "	150 "	175 "
66 "	18x60 "	166 "	180 "
82 "	20x60 "	200 "	215 "
100 "	22x60 "	245 "	270 "
120 "	22x72 "	285 "	315 "

water from various-sized roofs, under average conditions of rainfall.

Sizes of Galvanized-Iron Range Boilers. The dimensions and weights of both "Standard" and "Extra Heavy" galvanized-iron range boilers are given in Table VII.

Miner's Inch. A Miner's inch of water about equals 12 United States gallons per minute.

Sheet Lead. The weight and thickness of sheet lead are indicated in Table VIII.

TABLE VIII

Weight and Thickness of Sheet Lead

Weight Per Square Foot	Thickness
8 lbs.	$\frac{1}{8}$ in.
7½ "	$\frac{1}{9}$ "
6 "	$\frac{1}{10}$ "
5 "	$\frac{1}{12}$ "
4 "	$\frac{1}{15}$ "
3 "	$\frac{1}{20}$ "

Brass Piping. Table IX gives the weight per linear foot of brass pipe of standard iron pipe sizes.

TABLE IX

Weight of Brass Pipe

Iron Pipe Sizes

Size of Pipe	Weight Per Linear Foot	Size of Pipe	Weight Per Linear Foot
⅛ in.	.25 lb.	2 in.	4.0 lbs.
¼ "	.43 "	2½ "	5.75 "
⅜ "	.62 "	3 "	8.30 "
½ "	.9 "	3½ "	10.9 "
¾ "	1.25 lbs.	4 "	12.7 "
1 "	1.7 "	4½ "	13.9 "
1¼ "	2.5 "	5 "	15.75 "
1½ "	3.0 "	6 "	20.6 "

How to Make Rust Joints. The following five methods of making rust joints are in common use:

(a) Measure by weight, 2 parts of Flour of Sulphur, 1 part Powdered Salammoniac, 80 parts Iron Borings. Mix with water to a paste, and apply to the joint that it is desired to make. This sets quickly, and makes a good joint.

(b) Measure by weight, 1 part Flour of Sulphur, 2 parts Salammoniac, 200 parts Iron Borings. Mix with water to a paste and apply. This is longer in setting than the first combination, but makes a much stronger joint.

(c) Mix 10 parts Iron Filings and 3 parts Chloride of Lime to a paste by means of water. Apply to the joint, and clamp it in place. This will set solid in about 12 hours.

(d) Mix 80 parts of Iron Chips or Borings, 2 parts of Salammoniac, 18 parts of water to a paste, and apply to a joint. Sets slowly.

(e) Mix 5 pounds Iron Filings, 1 ounce Sulphur, 1 ounce Salammoniac, with water, to a paste. Apply to joint. Sets in from 3 to 5 hours.

To Find Centers between Fittings. To find the length of piping required to connect fittings where offsets occur—that is, to determine the distance between fittings, center to center, multiply the length of the offset, in inches, by the factors indicated as follows:

For	60-degree	or	1/6	bends,	multiply by	1.1547
"	45-	"	1/8	"	" "	1.4142

"	30-	"	1/12	"	"	"	2.00
"	22½-	"	1/16	"	"	"	2.61
"	11¼-	"	1/32	"	"	"	5.12
"	5⅜-	"	1/64	"	"	"	10.22

For example, suppose that it is desired to know the length between centers, of two 45-degree ells, when the offset is 2 feet (see accompanying diagram, Fig. 61 A). Since 2 feet=24 inches, we have:

24×1.4142=33.9+, or practically 34 inches, which, allowing off for the ells, will give the length of the pipe required.

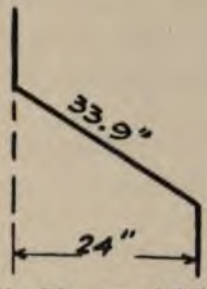


Fig. 61A. Diagram of Offset Ells.

TABLE X

Weights of Soil-Pipe per Foot

Size of Pipe	Standard	Extra Heavy
2 inch	3½ pounds	5½ pounds
3 "	4½ "	9½ "
4 "	6½ "	13 "
5 "	8½ "	17 "
6 "	10½ "	20 "
8 "	17 "	34 "
10 "	23 "	45 "
12 "	33 "	54 "

Capacity of Storage Tanks. As a basis for figuring the size of storage tank required, we may take the **average amount of water used daily by one person,** which is as follows:

Washing dishes	1	gallon per person daily.
House cleaning	2	" " " "
Washing clothes	3	" " " "
Toilet purposes and bathing	9	" " " "
Drinking	½	" " " "
In food	½	" " " "
Water closet	9½	" " " "

Total average of 25 gallons per person per day.

TABLE XI

Dimensions and Capacities of Wrought Steel Tanks

Dimensions	Capacity	Average Weight
5 by 24 inches	120 gallons	300 pounds
6 " 24 "	145 "	320 "
7 " 24 "	170 "	360 "
8 " 24 "	200 "	420 "
5 " 30 "	185 "	450 "
6 " 30 "	220 "	500 "
7 " 30 "	257 "	550 "
8 " 30 "	300 "	600 "
10 " 30 "	375 "	700 "
6 " 36 "	325 "	700 "
7 " 36 "	375 "	800 "
8 " 36 "	425 "	900 "
10 " 36 "	530 "	1,000 "
8 " 42 "	600 "	1,250 "
10 " 42 "	725 "	1,500 "
12 " 42 "	850 "	1,750 "

Tanks up to 6 by 22 inches are tapped 1 inch.

Tanks up to 10 by 30 inches are tapped 1½ inches.

Tanks above 10 by 30 inches are tapped 2 inches.

TABLE XII

Barometric Pressure at Different Altitudes, with Equivalent Head of Water, and Practicable Suction Lift of Pumps

Altitude	Barometric Pressure	Equivalent Head of Water	Practicable Suction Lift of Pump
At sea level	14.7 lbs. per sq. in.	33.95 feet	25 feet
½ mile, or 1,320 ft.	14.02 " " " "	32.33 "	24 "
½ " " 2,640 "	13.33 " " " "	30.70 "	22 "
¾ " " 3,960 "	12.66 " " " "	29.04 "	21 "
1 " " 5,280 "	12.02 " " " "	27.76 "	20 "
1¼ " " 6,600 "	11.42 " " " "	26.33 "	19 "
1½ " " 7,920 "	10.88 " " " "	25.13 "	18 "
2 " " 10,560 "	9.88 " " " "	22.82 "	17 "

TABLE XIII

Velocity and Volume of Discharge per Minute of Different Sized Sewers

Dia.	180 Ft. per Min. 3 Ft. per Sec.		270 Ft. per Min. 4½ Ft. per Sec.		360 Ft. per Min. 6 Ft. per Sec.		540 Ft. per Min. 9 Ft. per Sec	
	Fall	Gal.	Fall	Gal.	Fall	Gal.	Fall	Gal.
3 in.	1 ft. in 69 ft.	54	1 ft. in 30.4 ft.	81	1 ft. in 17.2 ft.	108	1 ft. in 7.6 ft	162
4 in.	1 ft. in 92 ft.	96	1 ft. in 40.8 ft.	144	1 ft. in 23 ft.	192	1 ft. in 10.2 ft.	288
6 in.	1 ft. in 138 ft.	216	1 ft. in 61.2 ft.	324	1 ft. in 34.5 ft.	432	1 ft. in 15.3 ft.	648
9 in.	1 ft. in 207 ft.	495	1 ft. in 92 ft.	742.5	1 ft. in 51.7 ft.	990	1 ft. in 23 ft.	1485

For example, a 6-inch sewer, laid to a grade of 1 foot, in 61.2 feet will have a velocity of 270 feet per minute, or 4½ feet per second, and will discharge 324 gallons per minute. Other grades and discharges can be similarly figured from the table.

The **friction loss caused by ells and valves in pipe work** can be calculated from the data of Table XIV.

TABLE XIV

Friction Equivalents of Ells and Globe Valves in Lengths of Straight Pipe

Diameter of Pipe	Ell in Feet of Pipe	Globe Valve in Feet of Pipe
¾ inch	3 feet	4 feet 0 inches
1 "	4 "	5 " 0 "
1¼ "	5 "	7 " 0 "
1½ "	6 "	8 " 0 "
2 "	7 "	10 " 0 "
2½ "	8 "	12 " 6 "
3 "	10 "	15 " 0 "
3½ "	12 "	17 " 6 "
4 "	14 "	20 " 0 "
4½ "	15 "	22 " 6 "
5 "	17 "	25 " 0 "
6 "	20 "	30 " 0 "
7 "	24 "	35 " 0 "
8 "	27 "	40 " 0 "
9 "	30 "	45 " 0 "
10 "	34 "	50 " 0 "
12 "	40 "	60 " 0 "
14 "	47 "	70 " 0 "

If, for example, it is desired to know the friction loss in a line of piping, caused by 2 ells and 1 valve, the size of pipe being 4-inch, by referring to the table, it will be seen that one 4-inch ell is equivalent in friction to 14 feet of pipe, and the 2 ells would therefore mean 28 feet, which, with 20 feet for the valve, would make a total friction equivalent of 28+20 feet, or a total friction loss equal to the friction loss in 48 feet of 4-inch pipe.

TABLE XV

Heat Units in Gases

1 cu. foot of Natural Gas will give off	900 to 1,000		B. T. U.
1 " " " Acetylene Gas	1,090		"
1 " " " Coal Gas	650 to	700	"
1 " " " Water Gas	300		"
1 " " " Producer Gas	120 to	150	"

TABLE XVI

Temperature of Various Flames

Gas-jet flame, with Oxygen	2,200°	Centigrade
Hydrogen flame in air	1,900°	"
Bunsen burner	1,871°	"
Acetylene	2,548°	"
Alcohol	1,705°	"
Denayrouze burner, ½ alcohol, ½ petroleum	2,053°	"
Oxyhydrogen flame	2,420°	"

Soil-Pipe Sizes Allowed by Various Cities. Municipal regulations ordinarily govern the sizes of soil-pipe that are allowed to be installed in towns and cities of any considerable size. The regulations in some of the leading American cities are indicated in the following:

Baltimore, Md. Buffalo, N. Y. Chicago, Ill. Cincinnati, Ohio. Denver, Colo. Detroit, Mich. Minneapolis, Minn. New Haven, Conn. Omaha, Neb. St. Joseph, Mo.

San Francisco, Cal.

Minimum diameter, 4 inches.

Alleghany, Pa. Pittsburg, Pa. Scranton, Pa.

For 1 to 4 water-closets, not less than 4 inches.
For 4 to 8 water-closets, not less than 6 inches.

Jersey City, N. J.

For 1 and less than 10 water-closets, with other fixtures, 4 inches.
For 10 and less than 20 water-closets, with other fixtures, 5 inches.
For 20 or more water-closets, with other fixtures, 6 inches.

Milwaukee, Wis.

For 4 water-closets, 4 inches.
For 10 water-closets, 5 inches.
For 25 water-closets, 6 inches.
For over 25 water-closets, 8 inches.

Newark, N. J. Paterson, N. J.

For main soil-pipe, 4 inches.
For main soil-pipe for water-closets on 5 or more floors, 5 inches.
For main soil-pipe for tenements or factories, 5 inches.

New Orleans, La.

For 1 to 5 water-closets, 4 inches.

For more than 5 water-closets, 5 inches.
In buildings over 5 stories, and having more than 8 water-closets, 6 inches.

Philadelphia, Pa.

For 1 to 6 water-closets, 4 inches.
For 7 to 12 water-closets, 5 inches.
For 13 to 20 water-closets, 6 inches.
If building is 5 up to 12 stories high, 5 inches.
If building is more than 12 stories high, 6 inches.

Rochester, N. Y.

For 1 to 30 fixtures, 4 inches.
For 30 to 50 fixtures, 5 inches.
For 51 or more fixtures, 6 inches.
One water-closet is counted as 2 fixtures; one tub, or sink, etc., is counted as 1.

St. Paul, Minn.

For main soil-pipe, not less than 4 inches.
For main soil-pipe for water-closets on 5 or more floors, 5 inches.

Cleveland, Ohio Columbus, Ohio

The maximum number of fixtures connected to pipe of various sizes is indicated as follows:

Size Pipe	Soil and Waste		Soil-Pipe Alone	
	Branch	Main	Branch	Main
4-Inch	48	96	12	24
5 "	96	192	24	48
6 "	168	336	42	84
7 "	280	560	70	140
8 "	420	840	105	210
9 "	580	1,160	145	290

10 "	800	1,600	200	400
11 "	1,060	2,120	265	530
12 "	1,420	2,840	355	710

Washington, D. C.

For 1 to 12 water-closets, 4 inches.
For 13 to 35 water-closets, 5 inches.
For 26 to 40 water-closets, 6 inches.

Toledo, Ohio

For main soil-pipe from 6 water-closets or bathrooms, 4 inches.
For main soil-pipe from 6 to 10 bathrooms or water-closets, 5 inches.
For main soil-pipe from more than 10 bathrooms, 6 inches.

A 3-foot urinal trough or wash-sink, or 1 bath, basin, sink, or small fixture, is counted as 1 fixture; and 1 water-closet, pedestal urinal, or slop hopper, is counted as 2 fixtures.

The above shows the sizes used in daily installations in various cities where local rulings govern, and all work is tested and inspected before being covered up by the other trades.

Rust spots on marble may be removed by applying a mixture of 1 part nitric acid and 25 parts water, then rinsing off with 3 parts water and 1 part ammonia.

Painting Galvanized Iron. First wash with vinegar, which roughens the surface, then apply the paint.

Painting Pipes in Greenhouses. Do not use asphaltum or tar paints in a greenhouse, as they

will injure the plants. Use a mixture of lampblack and boiled linseed oil, thinned with turpentine.

Cement for Iron and Marble. To cement iron to marble, use the following mixture: 30 parts plaster paris, 10 parts iron filings, 1 part sal ammoniac; mix to a fluid state with vinegar. Use at once, as it hardens rapidly.

To Cement Brass Work to Glass. Mix 2 parts litharge, 1 part white lead, 3 parts linseed oil, 1 part gum copal, and use immediately.

Cement for Porcelain. Soak 1 dram isinglass in water; pour upon this a sufficient quantity of alcohol to cover the isinglass; allow it to dissolve, placing it in a warm room. Next dissolve ½ dram of mastic in 1 fluid dram of rectified spirits of wine. Mix both solutions together; add ½ dram of powdered gum ammonias, and evaporate the mixture in a water bath until it is the right consistency. Keep the cement in a glass bottle. Warm before using, and also warm the part of the porcelain to be cemented.

A cement that will resist white heat is made in the following manner: Mix 4 parts pulverized fire clay, 1 part plumbago, 2 parts iron borings or filings free from oxides, 1 part peroxide of manganese, ½ part borax, ½ part sea salt. Mix to a stiff paste with water, and use immediately. Heat should be applied gradually the first time.

Grafting wax, to be used instead of putty

in setting water-closets, may be made as follows: Melt and thoroughly mix together, 3 lbs. mutton tallow, 5 lbs. beeswax, 10 lbs. resin. Pour into cold water, and work with the hands until the color of pulled molasses taffy. Keep in a tight can when not in use. This will make a tight joint where the closet joins the lead pipe, and will not dry out and crack like putty.

Cement mortar for setting closets on cement floors, is made as follows: Mix 3 parts Portland cement and 1 part fine sand.

To Harden Cast Iron. Cast iron can be hardened as easily as steel. Use the following formula: ½ pint vitriol, 1 peck salt, ½ lb. saltpeter, 2 lbs. alum, ¼ lb. prussic potash, ¼ lb. cyanide of potash. Dissolve in 10 gallons of rain water. Stir until thoroughly dissolved. Heat the iron to a cherry red, and dip into the solution. If the iron is to be very hard, reheat and dip the second or third time.

To Inscribe Metal. Cover the part to be marked, with melted beeswax; and, when cold, mark the desired inscription by cutting through the wax down to the surface of the metal. Now, with a mixture of ½ ounce of nitric acid and 1 ounce of muriatic acid, fill the inscription, using a feather. Allow this to remain for from one to ten minutes, and then throw on water to check the action of the acids. Remove the wax by heating. This is a good method of marking tools.

To find the **area of a rectangle,** multiply the length by the width.

To find the **area of a triangle,** multiply the base by ½ the perpendicular height.

To find the **circumference of a circle,** multiply the diameter by 3.1416.

To find the **area of a circle,** square the diameter and multiply by .7854; or multiply the diameter by the circumference, and divide by 4.

To find the **diameter of a circle of given area,** divide the area by .7854, and find the square root of the result.

To find the **diameter of a circle which shall have same area as a given square,** multiply one side of the square by 1.128.

To find the **number of gallons in a cylindrical tank,** square the diameter, multiply by the height (all dimensions in inches), and multiply by .34.

To find the **number of gallons in rectangular tank,** multiply the length by the breadth, and the result by the depth; and this result by 7.4 if these dimensions are in feet. If the dimensions are in inches, multiply by .004329.

The find the **lateral pressure of water upon the side of a tank,** multiply the area of the submerged side (in sq. in.), by the pressure due to ½ the depth. Suppose, for example, a tank to be 12 ft. long and 12 ft. deep, what is the pressure on the side wall? We have: $144 \times 144 =$ 20,736 sq. in. Since a cubic foot of water weighs 62.5 lbs., then the weight pressing on 1 sq. in.

of the bottom of the cube will be 62.5÷144=.43 lb. And, since the water is 12 ft. deep, we have: 12×.43=5.16 lbs. pressure per sq. in. at bottom of tank. Pressure at top=0; therefore the average pressure on the side of the tank, or the pressure at mid-depth will be 5.16÷2=2.6 lbs., approximately. Therefore, 20,736×2.6=53,914 lbs. pressure on side of tank.

To find the **number of gallons in a foot of pipe of any size,** multiply the square of the diameter of the pipe (in inches) by .0408.

To find the **diameter of pipe to discharge a given amount of water per minute in cubic feet,** multiply the square of the quantity in cubic feet per minute, by 96. This gives the pipe diameter in inches.

To find the **power necessary to raise water to any given height,** multiply the number of cubic feet required per minute by the number of feet through which the water is to be raised. Then multiply this result by 6.23, and divide by 33,000, which will give the nominal horse-power required. If the amount of water required per minute is in gallons, the multiplier should be 8.3 instead of 6.23.

Another method of finding the horse-power required to raise water to a given height, is to multiply the pounds of water by the height to be raised in feet, and divide by 33,000. Add to this result about 25 per cent to offset friction and other losses.

Water expands about 1/10 of its volume in freezing, and about 1/20 in boiling.

To find the **area of a required pipe when the amount and velocity of the water are given,** multiply the number of cubic feet of water by 144, and divide this amount by the velocity in feet per minute.

To find the **diameter of a pump cylinder to move a given quantity of water per minute,** 100 feet of piston travel being the standard, divide the number of gallons by 4, and take the square root of the result. This will give the diameter in inches.

To find the **velocity in feet per minute necessary to discharge a given volume of water in a given time,** multiply the number of cubic feet of water by 144, and divide the result by the area of pipe in inches.

PLUMBING IN OFFICE BUILDINGS

The plumbing work in office buildings, while it may run up to a considerable sum of money, on the whole consists only of a number of small jobs bunched together in one large one.

It often happens that the main sewer in the street is higher than where the main sewer from the building is required to leave the building. This requires the use of some mechanical means to deliver the sewage from the building into the main or street sewer.

Sewage Ejectors. Fig. 62 shows a type of **sewage ejector** or **sewer lift,** known as the

MODERN HIGH-TANK TYPE OF CLOSET.

"Ellis," which is used very extensively. By means of this apparatus, all the sewage of a building can be discharged in a simple, sanitary, and economical manner, without coming in contact with the air of the building; and at the same time, the entry of sewage or sewer gas from the

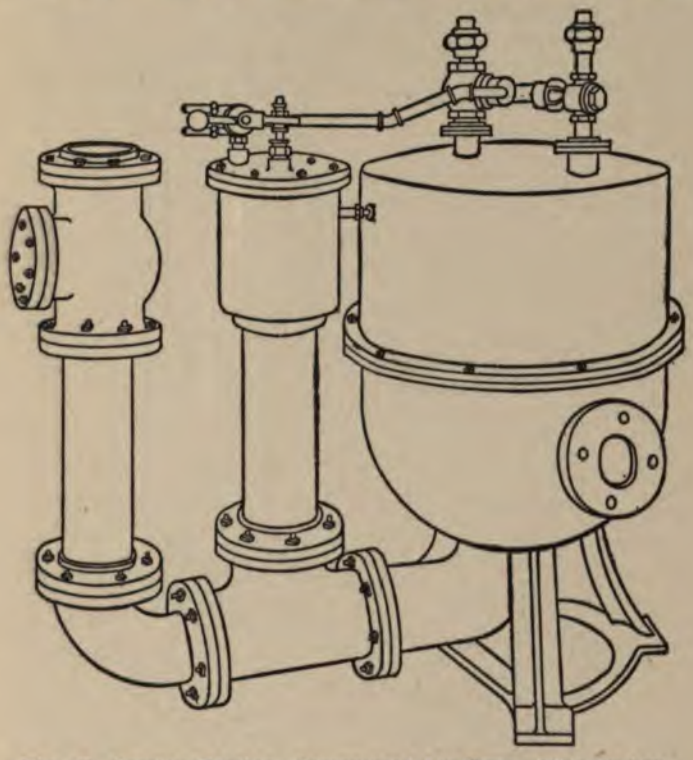


Fig. 62. Sewage Ejector—Compressed-Air Type—Ellis System.

street sewers is an impossibility. The motive power in this ejector may be either compressed air, steam, electricity, or water. It is applied in the following manner: In a chamber built of

brick or iron, either in the basement floor or outside the building, an air-tight iron vessel, called a "receiving tank," is placed at such a

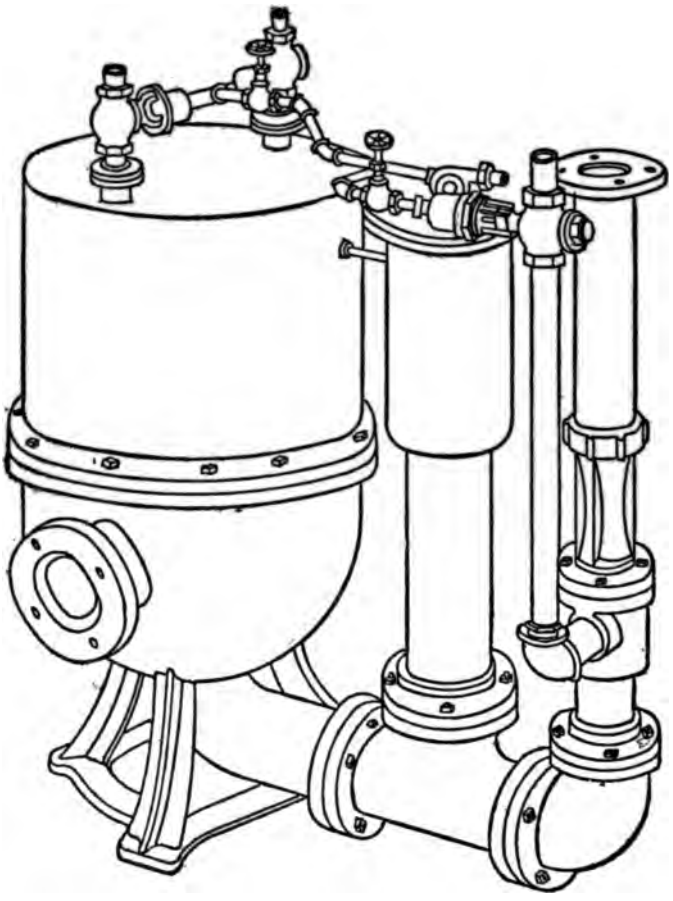


Fig. 63. Steam and Air Type of Sewer Lift—Ellis System.

level that all the sewers and drains of the building can have a good fall into it. From the receiving tank, a discharge pipe is laid to the

point of outfall, which is generally the street sewer. The action of the ejector is as follows:

The sewage flows from the drains, through the inlet-pipe, into the receiving tank, and gradually rises therein until it reaches the under side of the float. The air inside the float being at atmospheric pressure, causes the float to rise with the sewage, thus opening an operating valve, whereupon the compressed air, thus automatically admitted into the receiving tank on the surface of the sewage, drives the entire contents before it, through the opening at the bottom and through the outlet pipe, into the iron sewage-discharge pipe. This is the only way sewage can escape from the receiver, as the instant the air-pressure is admitted upon the surface of the sewage, a check-valve in the inlet-pipe closes, and prevents the liquid from escaping in that direction.

The sewage passes out of the receiver until its level falls to such a point that the tank is thoroughly empty, reversing the action of the operating valve which first cut off the supply of sewage to the ejector. The valve in the outlet-pipe then falls on its seat, retaining the liquid in the sewage-discharge pipe; the sewage again flows through the inlet-pipe, and the tank begins to fill again, and this action continues as long as there is any sewage flowing into the tank.

The system can be cross-connected with air, steam, or water, and arranged with by-pass

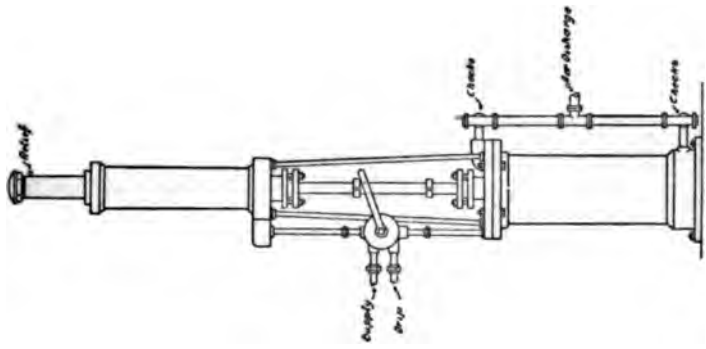


Fig. 65. Automatic Hydraulic Air-Compressor.

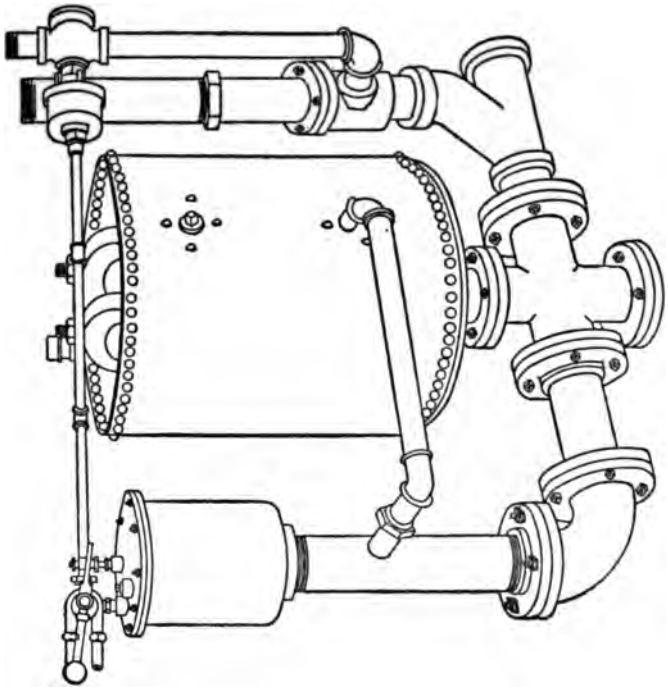


Fig. 64. Sewage Ejector Operated by Steam—Ellis System.

valves operated by hand if desired. Fig. 63 shows an ejector of the steam and air type.

There are a number of good points about this type of sewage ejector, which can be summed up as follows:

It works entirely automatically.

The working parts are reduced to a minimum, and are of a kind that are not apt to get out of order.

The receiving tank into which the sewage enters, contains no finished surface, such as is unavoidable in pumps and is rapidly destroyed by the action of sewage, sludge, and grit. In the ejector, there is nothing to prevent the free flow and it is made of a composition upon which the sewage can produce no detrimental effect. Neither stuffing-boxes nor sliding device come through the tank.

The friction of a pump piston or other working part is avoided. The pressure itself, acting directly upon the fluid without the intervention of any machinery, forms a practically frictionless and perfect piston, past which there can be no slip or leak whatever.

The only finished parts are the inlet, discharge valve, and the automatic, which are accessible, and these only make one move at each discharge of the ejector. The float, being filled with air, will always retain its buoyancy. The sewage inlet and outlet valves are designed to give a passageway the full area of a pipe,

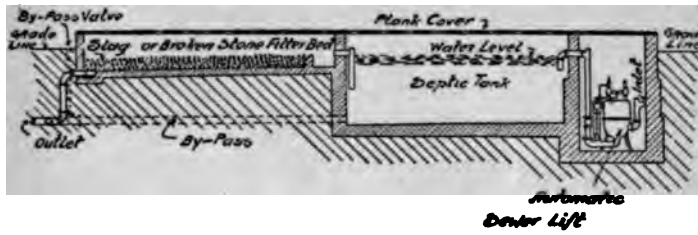


Fig. 66. System of Sewage Disposal for Towns where Proper Natural Gravitation is Unattainable.

allowing a full outlet to all the solids that the sewer can carry.

The receiver forms a complete severance of the house drains from the street sewers, thereby

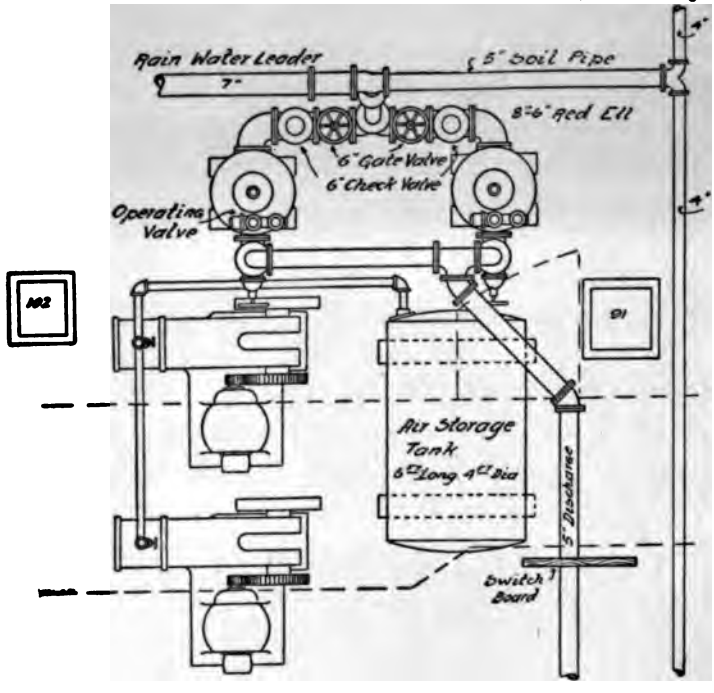


Fig. 67. Plan of Sewage-Ejector Plant, Custom House, New York City.

creating an absolute bar to any back action from the sewer.

The ejector can be operated by steam, compressed air, or water; and its use renders it possible to have a perfectly dry and sanitary basement at any depth, without regard to the depth of the street sewer.

The receiving tank is so constructed that it is thoroughly emptied at each discharge. It has no working parts whatever, and is arranged to discharge from 100 to 2,000 gallons per minute.

Fig. 64 shows a type of ejector which is operated by steam.

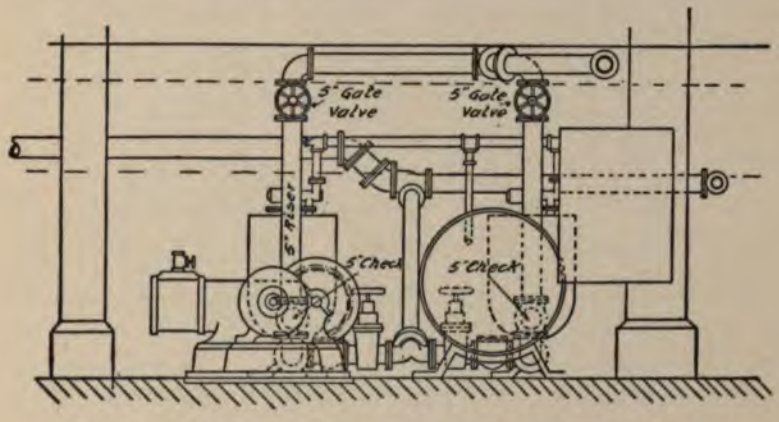


Fig. 68. Elevation of Sewage-Ejector Plant, Custom House, New York City.

Fig. 65 shows an **automatic hydraulic air-compressor** which is operated by the water pressure from the street. It requires no attention when once started, and can be placed in any position. It is especially adapted to installa-

tions where only a limited supply of compressed air is required.

Fig. 66 shows a system for towns or cities where proper gravitation cannot be obtained, and is very effective.

Figs. 67, 68, 69, and 70, show plans and elevations of a duplicate plant for handling the sewage in the new Custom House, New York City, where there is being installed a duplicate plant of 100-gallon automatic ejectors. These

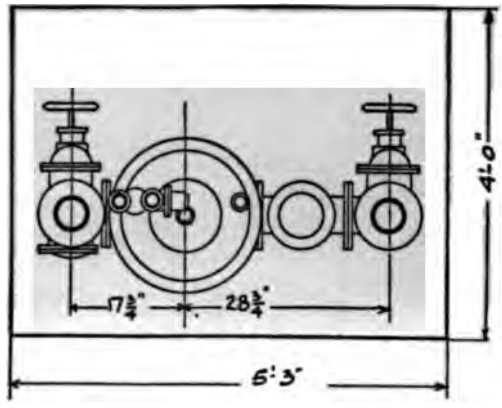


Fig. 69. Part Detail of Compressed-Air Sewage-Ejector Plant, Custom House, New York City.

ejectors will take the place of the centrifugal pumping plant formerly installed. Compressed air is the motive power; and under normal-condition tests, the ejectors discharged their contents in eight seconds, under a consumed pressure of 15 pounds.

As is shown in Fig. 70, the float arrangement operates on a central pole, and the inlet and outlet flows are through cylinders equipped with

the necessary flap and gate checks. The operation of the valves and air-plunger is simplified by the action of a two-way cock attached to the trip valve.

An important improvement incorporated in the latest types of ejectors is the plunger rod, which is packed at its seat bearing in a way that precludes the possibility of escape and loss of

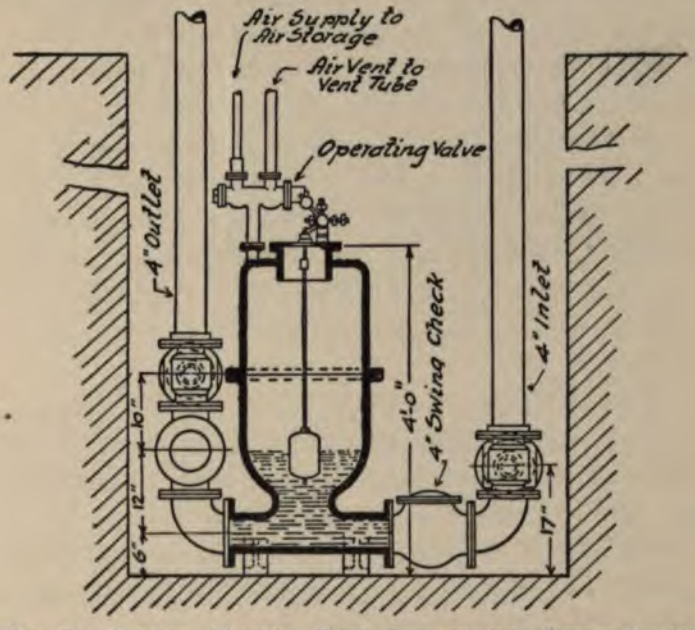


Fig. 70. Diagram Showing Float Arrangement, Sewage-Ejector Plant, Custom House, New York City.

air. The new float arrangement insures a uniform operation in the air-control, and also prepares for a complete discharge of the ejector contents. The two compressors for this plant have a capacity of 52 cubic feet at 150 revolu-

tions per minute. The motors are 7½ horsepower, at 50 pounds pressure. The vertical lift is 46 feet; and the distance from the ejectors to the street sewer is 105 feet. The plant is designed to take care of the drains from the south end of the building and all the flow that comes from the roofs and extensions.

The size of the flow and discharge pipes for any installation will depend, of course, on the amount of sewage to be handled; and this can be readily determined. Allow one pound of air-pressure per foot of lift.

Drainage Fittings. In the roughing-in of the pipe work in office buildings, we may have to use either cast-iron, or wrought-iron, or steel **screw-jointed pipe.** The specifications for the job will cover this point. The principles involved will be the same whatever material is used.

The fittings used on the screw-joint system, and called **recessed drainage fittings,** and are made of cast iron, like cast-iron steam fittings; but the recessed feature enables a smooth joint to be made where the pipe-end stops when screwed up tight, and thus reduces the chances for stoppages at these points.

Drainage fittings are made **plain, coated with asphaltum,** or **galvanized.** Drainage fittings should be used entirely on the drain, soil, and waste work; but the ordinary cast-iron or malleable fittings (plain, asphalted, or galvanized) may be used on the vent piping.

Fig. 71 illustrates a full line of drainage fittings.

It is customary, in many buildings of this class, to bunch the fixtures on one or two floors, where they will be the most convenient for the greatest number of tenants; and the elevator

Fig. 71. Types of Drainage Fittings.

Fig. 71 (Continued). Types of Drainage Fittings.

service renders this possible. This does away with a toilet-room on each floor, and allows of more sanitary work being installed, as regards the fixtures, manner of installing, and the finish of the toilet-room itself. Frequently, toilet-

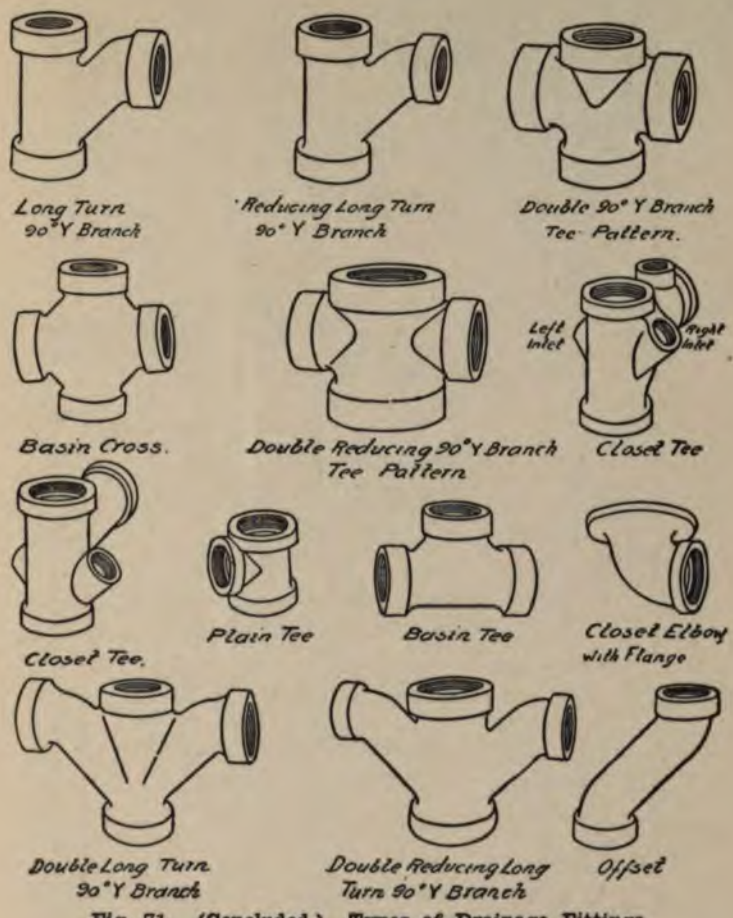


Fig. 71. (Concluded.) Types of Drainage Fittings.

rooms on each floor of buildings of this class, do not get the service necessary to keep them in a sanitary condition; but the one or two toilet-rooms, with a large number of fixtures, demand that they be kept in clean and orderly condition, and are nearly always found in that condition.

Where it can be used, Fig. 72 illustrates a

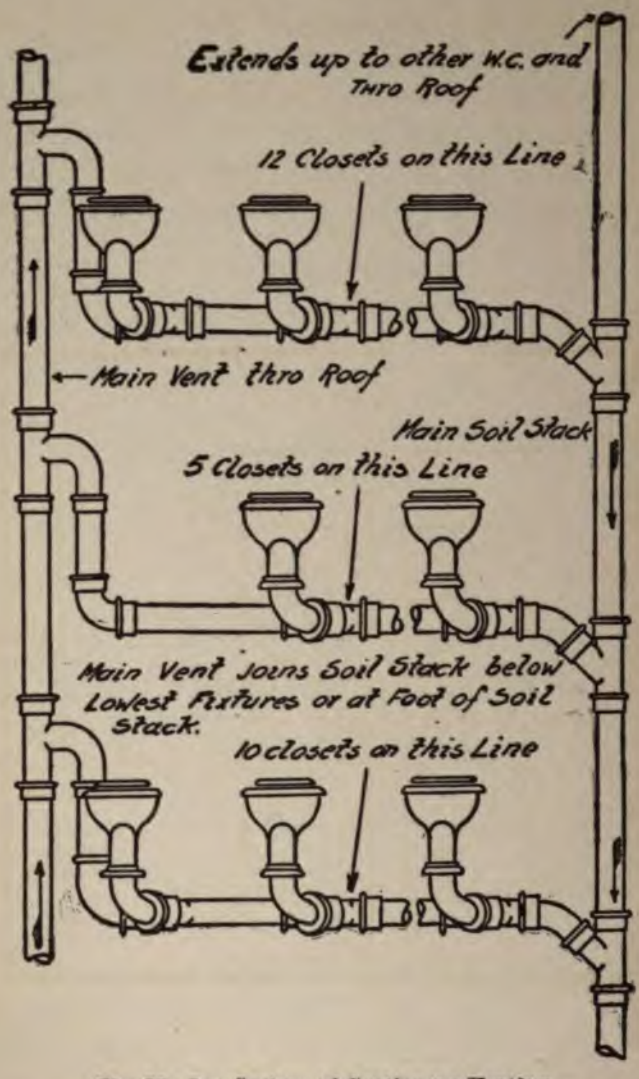

Extends up to other W.C. and Thro Roof
12 Closets on this Line
← Main Vent thro Roof
Main Soil Stack
5 Closets on this Line
Main Vent joins Soil Stack below Lowest Fixtures or at Foot of Soil Stack.
10 closets on this Line

Fig. 72. One System of Continuous Venting.

system of **continuous venting** that gives excellent results; but the location of the toilet-

room and the fixtures will not permit of this style in every job.

Both the soil- and vent-stacks extend up through the roof, and the arrangement of the pipe work almost entirely eliminates danger of siphonage. The main vent-pipe should connect

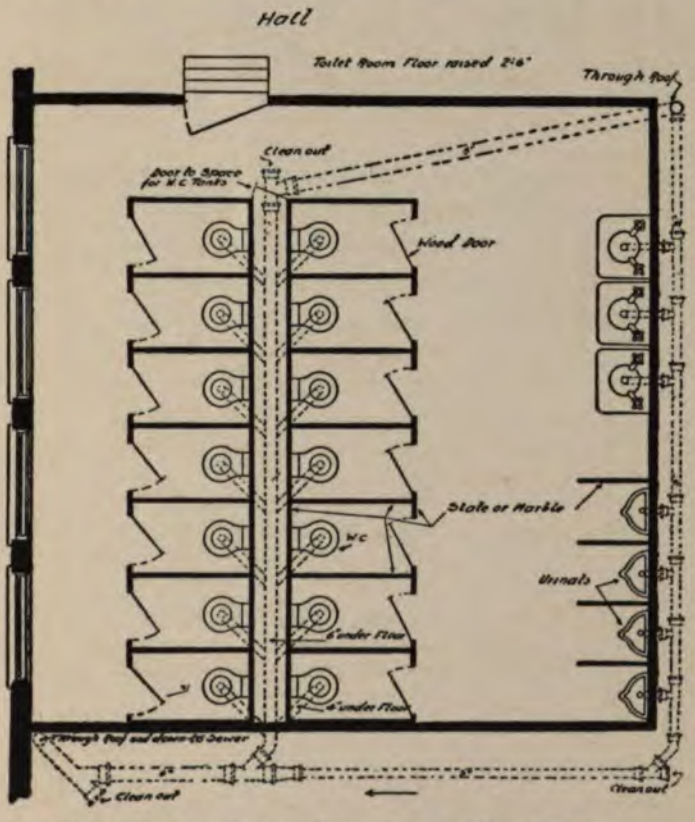


Fig. 73. Plan of Toilet-Room for an Office Building.

to the soil-stack below the lowest set of fixtures, which will permit any dirt or scale in the vent-

pipe to drop into the soil-stack and be flushed through to the sewer.

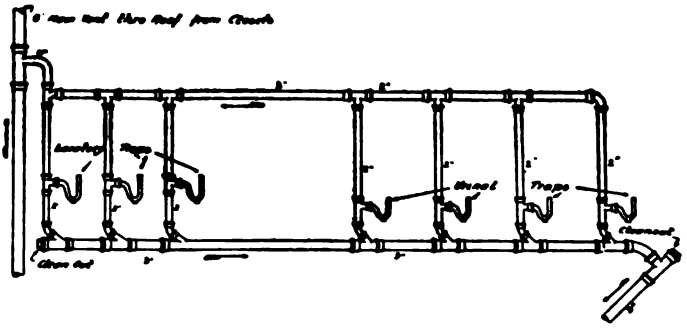


Fig. 74. Elevation of Waste- and Vent-Piping for Urinals and Lavatories in Office Building Toilet-Room.

Fig. 73 shows a floor-plan of a typical toilet-room for buildings of this class.

The number and style of fixtures may be

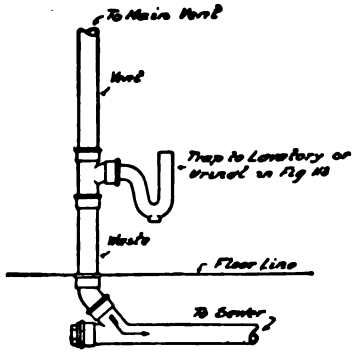
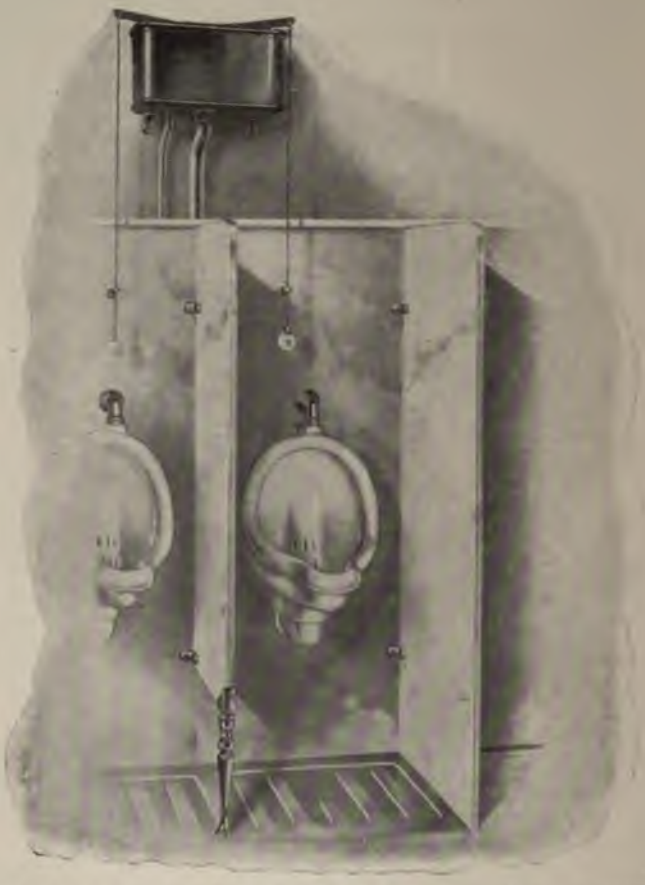


Fig. 75. Waste- and Vent-Piping for Single Fixture.

varied to suit requirements. The floor of the toilet-room is raised about 2½ feet above the hall floor, and this permits of the roughing-in, without any great amount of cutting or notching of timbers, and gives ease of access in case of



RANGE OF SIPHON-JET URINALS WITH HAND FLUSH.

necessary repairs or to clear stoppages. Clean-out plugs are placed at convenient points to permit of easy access to the interior of the waste piping. The closet tanks go in the space between the stall partitions, as shown in Fig. 77.

Fig. 74 is an elevation of the waste- and vent-piping for the urinals and lavatories. This style of venting does away with the possibility of the vents becoming clogged up, as might happen—and very frequently does—when the vent-pipe is taken from the crown of the trap.

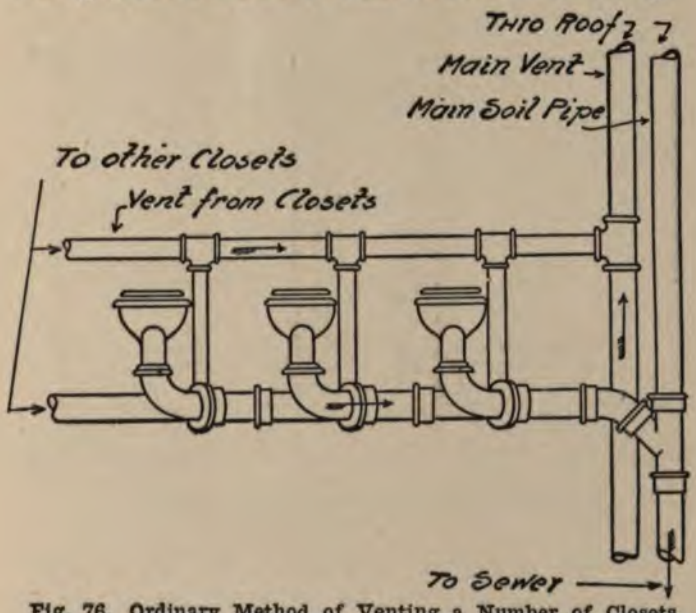


Fig. 76. Ordinary Method of Venting a Number of Closets.

Fig. 75 is an elevation of the waste- and vent-piping for a single fixture as shown in Fig. 74. The good points of this style of work can be readily noted.

[illegible] shows the ordinary method of venting a [illegible].

A comparison of Fig. [illegible] with Fig. 76 will show [illegible] points in the latter.

Fig. [illegible] is an end elevation of the closet stalls, and can be readily understood. Either high or low-down flush-tanks can be used. Sufficient room must be left between the stalls to permit of entrance for necessary repairs.

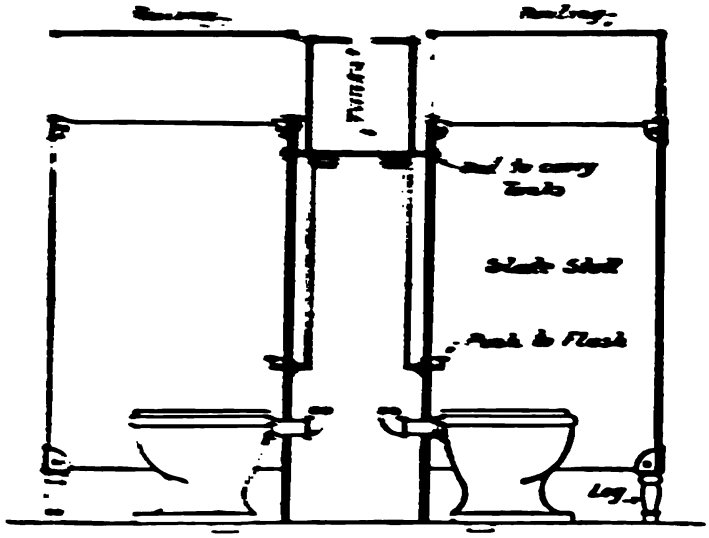


Fig. [illegible]. End Elevation of Closet Stalls.
Flush tank to each closet.

Fig. 75 shows a side view of the urinals. The system of waste- and vent-piping is shown in Figs. 74 and 75.

There may be a single automatic flush-tank for each urinal; or one flush-tank for the battery of urinals; or each urinal may be connected

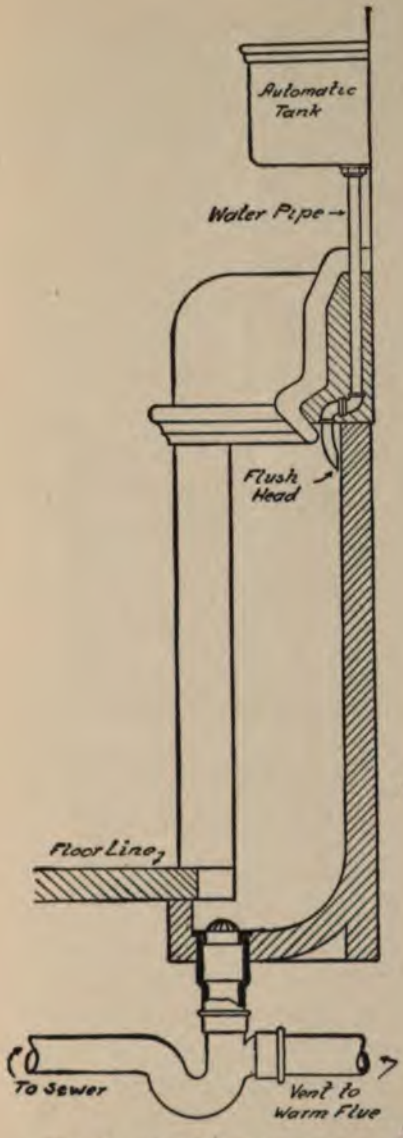


Fig. 78. Side View of Siphon-Jet Urinal.

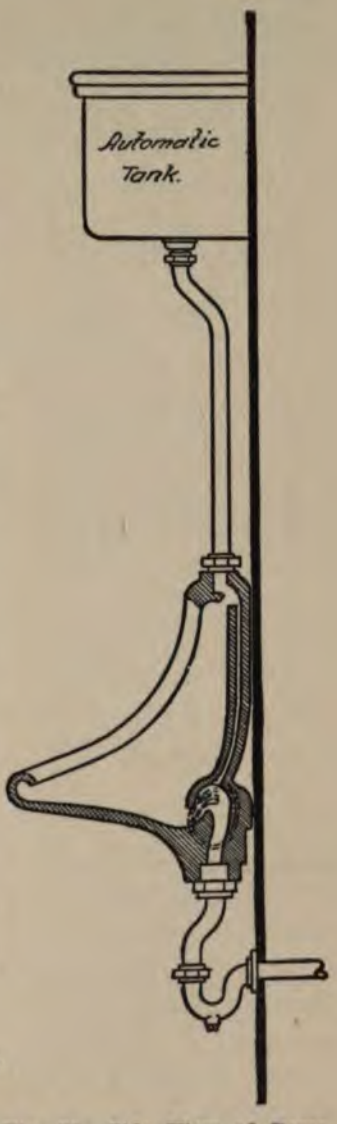


Fig. 79. Side View of Porcelain Urinal.

direct to the water supply, and be provided with a compression or self-closing urinal cock. The automatic tank is preferable, as it insures the urinals being flushed at regular intervals, and

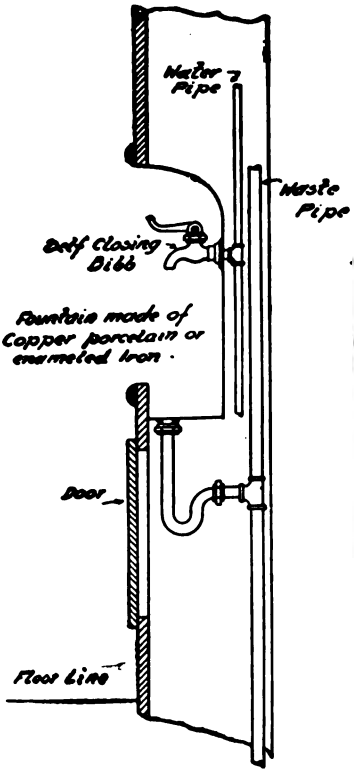


Fig. 80. Side View of Drinking Fountain, Showing Manner of Running Waste and Water Supplies.

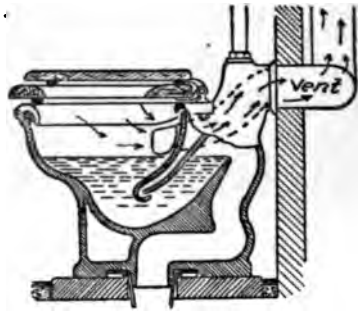


Fig. 81. Water-Closet with Vent Connected to Heated Flue.

keeps them in a more sanitary condition. It takes water to keep things clean; so do not be afraid to use it; and this applies to the toilet-room and its contents.

Fig. 79 is a side view of a porcelain urinal, and shows the manner of running the waste- and vent-pipes. The vent-pipe in this case is carried to a warm flue; and this removes any odor from the fixture, besides tending to create a circulation of air through the toilet-room.

Fig. 80 is a side view of a **drinking fountain,** and shows the manner of running the waste and water supplies. This class of fixture does not permit of any great quantity of water entering the waste-pipe at any one time; so the danger from siphonage is slight, and the waste-pipe from the fountain can be branched directly into the waste-pipe as shown. The upper end of the waste-pipe should enter the main vent-pipe or be carried through the roof.

In some cases the water supply for the fountains is carried into a box which is filled with ice, sufficient pipe being placed in the box to allow a quantity of water to cool, which is then run to the fountains.

The **main water supply** for this class of buildings may be taken directly from the street mains. In case the pressure is light, or the building is a high one, it will become necessary to provide some means of forcing the water to the fixtures, and this calls for the use of a **pump,** with a **storage tank** above the highest fixtures, or a **compression or closed tank** in the basement. The pump, in either case, can be so connected that it will shut off when a certain height or certain pressure of water is reached, and will

start automatically when the supply falls below this point. This pump can be operated either by steam or by electricity.

Hot water can be supplied to the fixtures by one of the methods already described.

Fig. 81 shows a type of water-closet that is

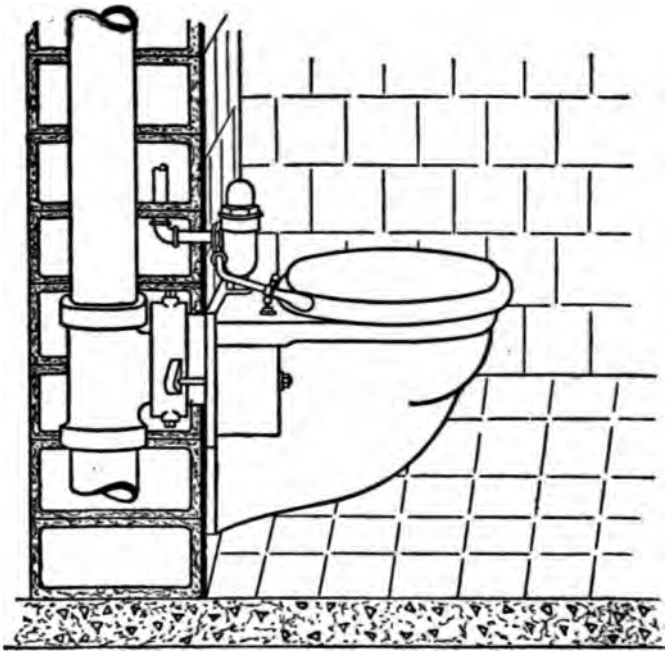


Fig. 82. Water-Closet Suspended from Wall.
No cutting through floor necessary.

being used in many of the better grades of plumbing installations. The raised rear vent is connected to a heated flue, and this creates a rapid circulation of air from the room, thoroughly removing any odors.

Fig. 82 shows a type of closet that is sus-

pended from the wall. This does away with the necessity of cutting holes through the floors, and is especially adapted to buildings of steel or reinforced-concrete construction. This makes a very neat and sanitary fixture.

Flush-Valves. Fig. 83 shows a valve for

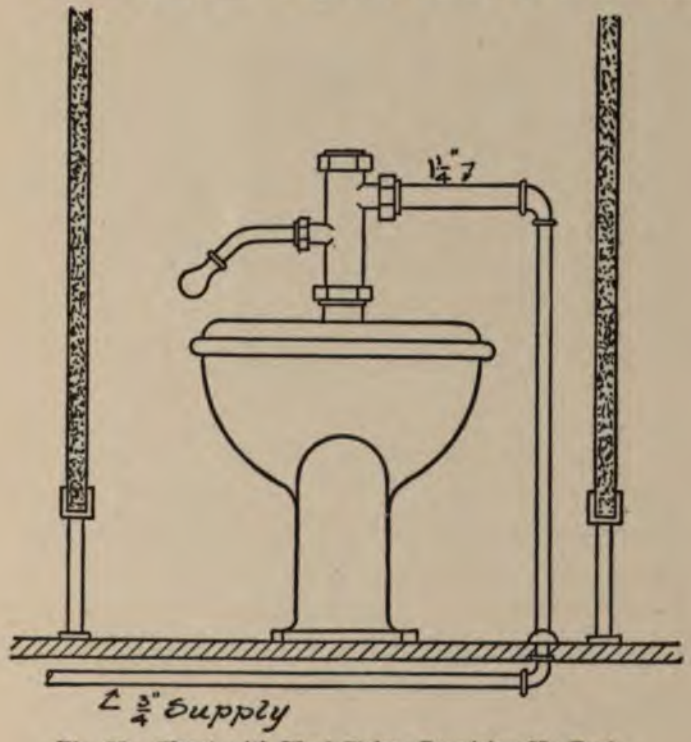


Fig. 83. Closet with Flush-Valve, Requiring No Tank.

flushing water-closets that does away with the tank. These valves are used very extensively where there are a large number of fixtures, and where it is desired to give any one fixture a given amount of water during the flushing

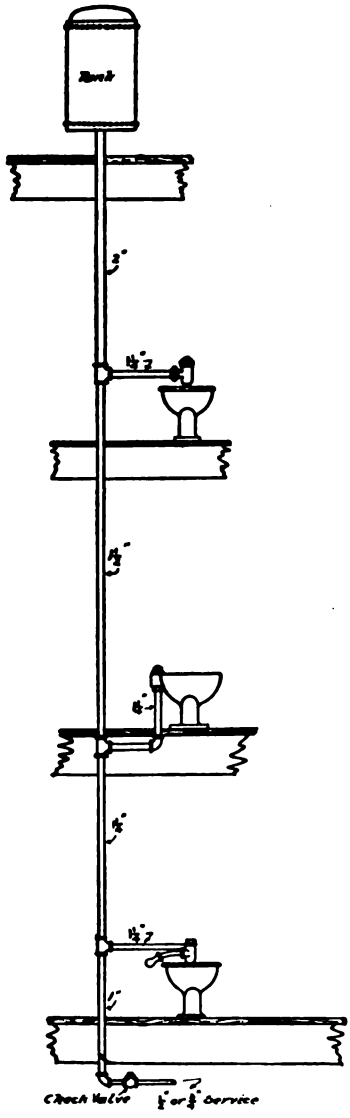


Fig. 84. Closet Installation where Water Pressure Is Light and Supply-Pipe Small.

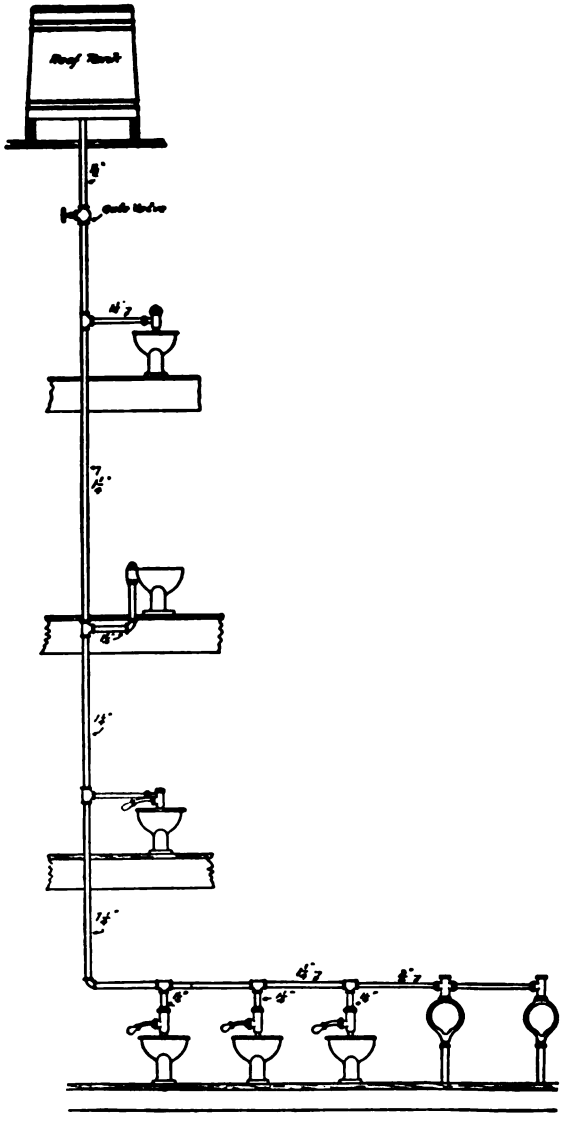


Fig. 85. Closets and Urinals Supplied from Tank above Highest Fixture.

process. The figure shows the manner of connecting up the valve when there is a very heavy pressure, say 80 pounds or more; it is as simple as making a connection for a sink bibb.

Fig. 84 shows a method of installation where the water-supply pressure is light, and the supply-pipe is small. A small, closed tank, or a chamber made of pipe, is placed above the highest fixture, at any convenient point; and this will give ample pressure and volume of water to operate the valves successfully. The successful working of valves of this type depends entirely upon two factors—namely, sufficient pressure and sufficient volume of water. They may be regulated to discharge nearly any amount of water desired for thoroughly flushing a fixture, and are usually required to discharge from 6 to 10 gallons in from 10 to 15 seconds' time, after which they shut off the water until operated for the next flushing.

Fig. 85 shows a number of fixtures supplied from a tank placed above the highest fixtures, either in the attic or on the roof. This tank can be supplied with water through a ball-cock which will allow water to enter the roof tank when any is used for flushing the fixtures. Three different styles of valves are shown on the closets. The size of piping will be varied as fixtures are added or removed.

Fig. 86 shows a number of fixtures supplied with flush-valves where the pressure is ample to reach above the highest fixtures, and the

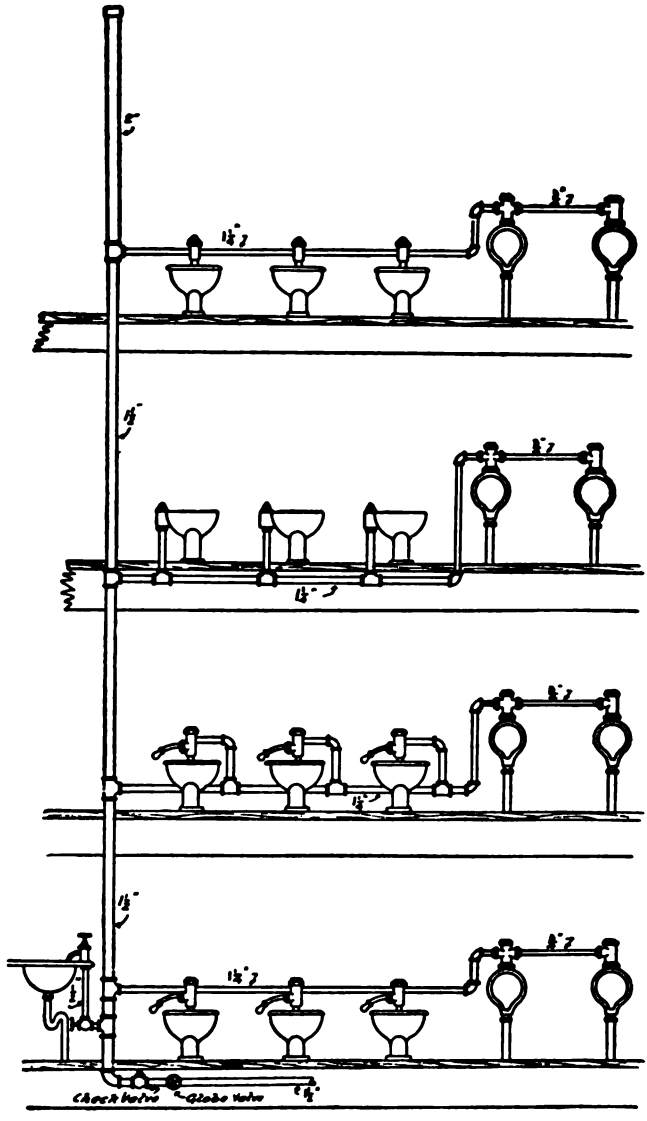


Fig. 86. Fixtures Supplied with Flush-Valves where Pressure is Ample and Stand-Pipe Large.

stand-pipe will insure a sufficient volume of water to flush all fixtures thoroughly.

Fig. 87 shows a number of fixtures supplied with flush-valves where the water pressure is strong, but the service pipe from the street is small in size.

The stand-pipe will furnish a sufficient volume of water to insure the thorough flushing of all the fixtures.

Fig. 88 shows a **measuring basin-cock** that can be set to give a certain amount of water each time it is operated, closing off when this amount has passed through it.

Fig. 89 shows a urinal valve that can be set to give a certain amount of water each time it is operated.

FACTORY PLUMBING

This is a branch of plumbing to which too little attention has heretofore been paid, and is a very profitable field if gone after properly. A trip through a number of factories will, in the majority of cases, reveal almost anything but sanitary conditions—with all due respect to the manufacturers. If the manufacturer would consider for a moment the fact that if he should provide clean accommodations for his employees, there would be a tendency on their part to greater neatness in work; there would also certainly be a saving in time over the present system, under which employees have in some cases to go a considerable distance to find toilet

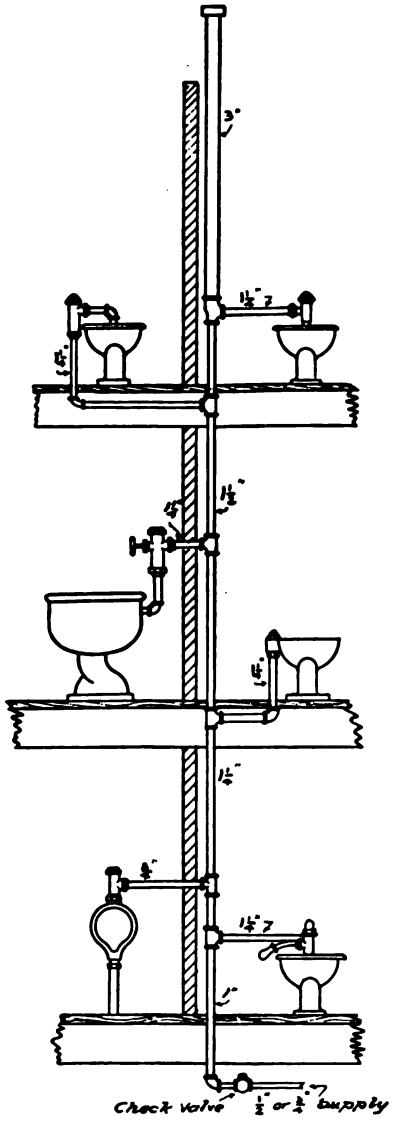


Fig. 87. Fixtures Supplied with Flush-Valves where Pressure is Strong but Service Pipe Small.

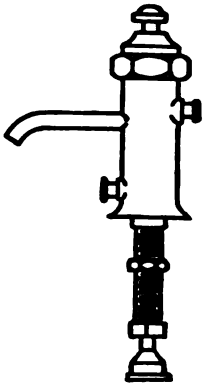


Fig. 88. Measuring Basin-Cock.

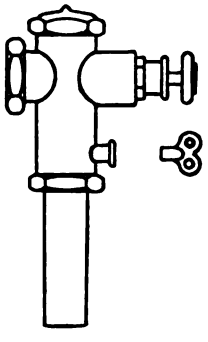


Fig. 89. Measuring Urinal Valve.

accommodations. The subject of toilet-rooms is well worth the consideration of any manufacturer, from any point he cares to look at it.

Fig. 90 shows a floor-plan of a **model toilet-room.** The number of fixtures may be increased or decreased to suit the conditions. The building may be constructed of either brick or wood. The figure shows a room 20 feet wide, 30 feet long, and 14 feet in height, built of brick; with a cement floor; the side walls cemented 6 feet from the floor; and all woodwork painted with a good grade of waterproof paint. This allows the attendant to wash the entire room thoroughly at night, with a section of hose, thus putting the room in a thoroughly clean condition for the next day's use. The floor slopes to a deep **floor-drain,** which allows the water to escape rapidly, but which retains all dirt. By lifting the strainer, this dirt may be easily removed.

The wash sinks are 10 feet in length, made of cast iron, enameled inside, and resting on iron standards. The waste has a standing plug which allows about 5 inches of water to stand in the sink if desired; or, by removing the plug, the water may run away at once. The hot and cold water is supplied through **compression faucets,** the number of which may be increased or decreased as desired. Individual wash-stands may be installed if desired, and this is a matter for the owner to decide. The closets are **seat-operating;** that is, the tank fills when the

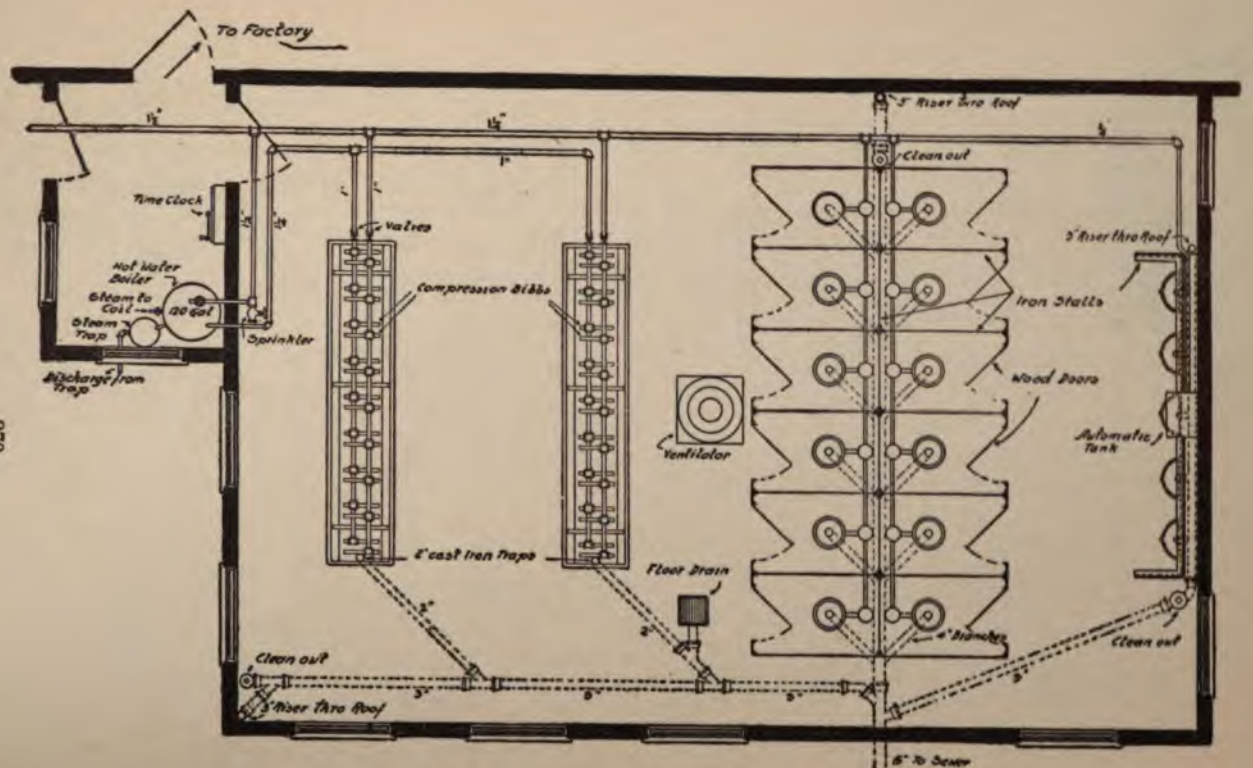


Fig. 90. Floor-Plan for Model Toilet-Room for Factory.

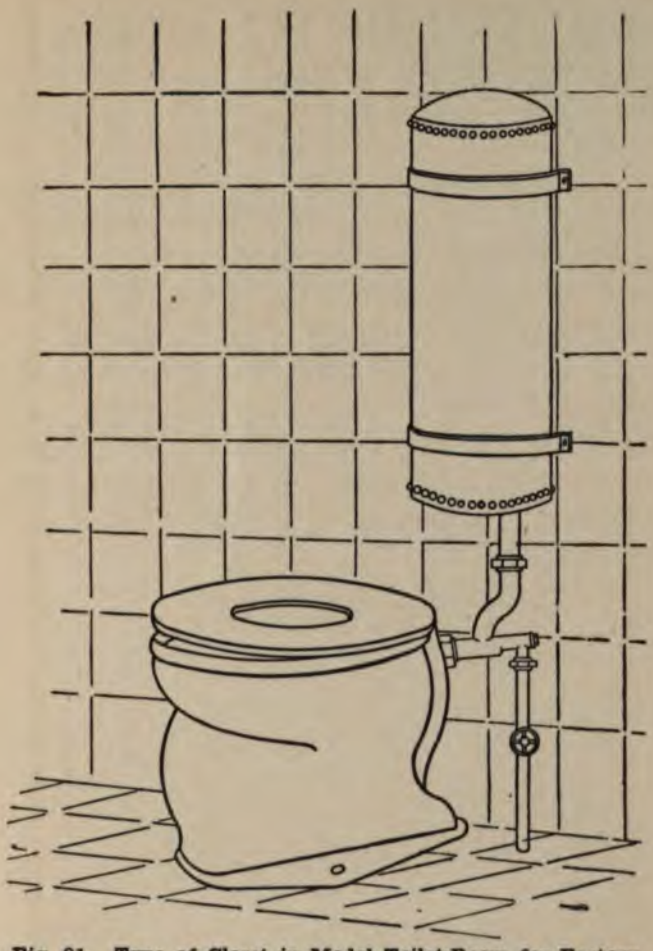


Fig. 91. Type of Closet in Model Toilet-Room for Factory.

closet is in use, and flushes when the seat is vacated. Fig. 91 is an illustration of the closets.

Each closet has a cut-off valve in the supply-pipe to the tank, so that, in case of repairs to the flush-valve, the water need not be shut off the

balance of the fixtures. The closets are cast iron, enameled; and the tanks are of galvanized iron. The closet stalls, and also the urinal stalls, are made of cast iron; and the doors of the closet stalls are made of wood. The urinals are of the flat-back type, cast-iron, enameled, and are flushed from an automatic flush-tank. Fig. 92 shows a front elevation of the urinals. Each urinal is separately trapped.

The hot water is supplied from a 120-gallon, galvanized range boiler, with a steam coil inside, as per Fig. 93; and the condensation is trapped to a **blow-off tank** in the yard, before going to the sewer. The object of the blow-off tank is to

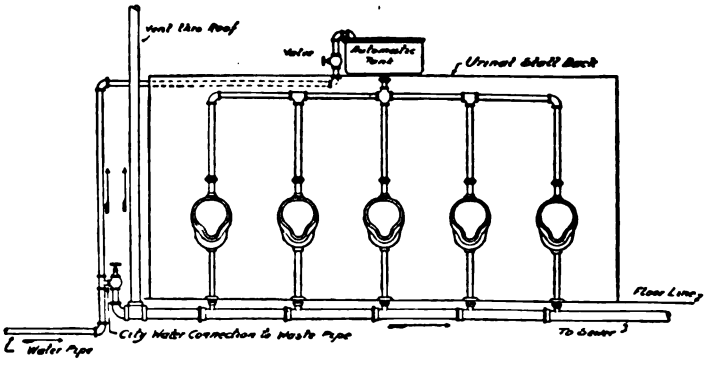
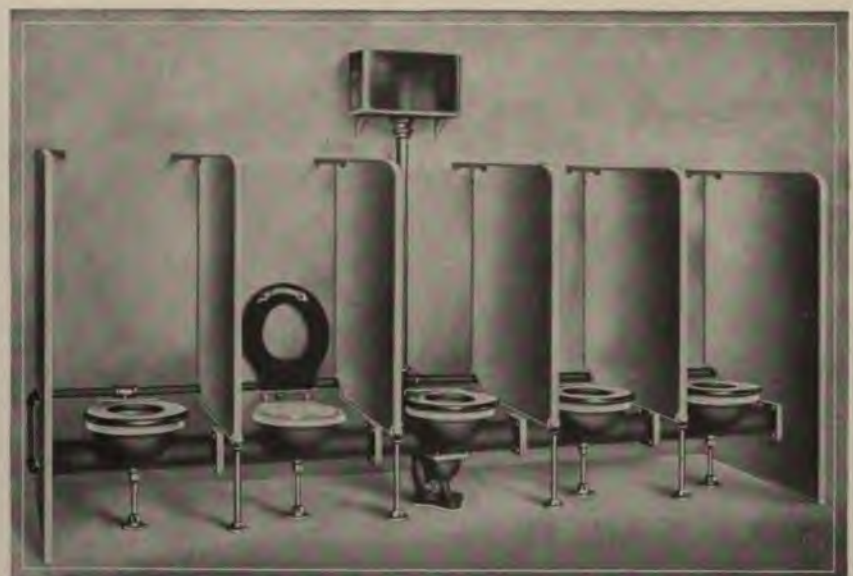


Fig. 92. Front Elevation of Urinals in Model Toilet-Room for Factory.

cool the condensation before allowing it to enter the sewer. Steam should never be connected directly to any sewer, as it soon causes the sewer pipe to deteriorate, and will start the joints to expand, where they are leaded joints, thus damaging the sewer.



RANGE OF CLOSETS FOR FACTORY, SCHOOL, OR PUBLIC BUILDING.

The proper sized steam coil to use for this boiler, with steam at different gauge pressures, can be determined from tables already given.

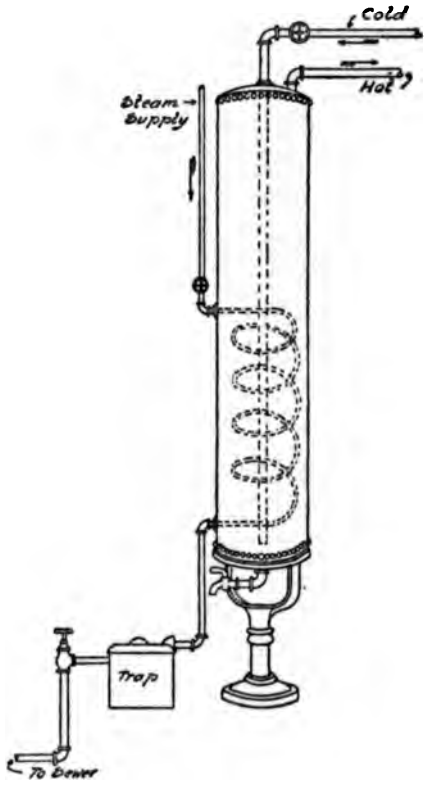


Fig. 93. Boiler with Internal Steam Coil for Heating Water Supply for Factory Toilet.

The main soil-pipe may be trapped or not, where it enters the building; and local rulings usually cover this point. From a careful study of the soil- and waste-pipes shown in Fig. 90, it will be seen that the siphoning of any of the fixtures is not very apt to occur. **Clean-out plugs**

are placed at points which give free access to the entire drainage system without disturbing any floor, in case of a stoppage. This is a point which should be considered in all plumbing installations.

In Fig. 92 it will be noticed that the city water is connected to the end of the urinal waste-pipe. This allows for the thorough flushing of this pipe in case of a stoppage.

A ventilator placed in the roof will carry away any odors from the room.

The water piping is of galvanized iron, of the sizes shown.

Provision must be made for heating and lighting the room during the winter season.

PRIVATE OR PNEUMATIC WATER SYSTEMS

Private or pneumatic water systems may be used in country and city homes, factories, large buildings, etc., where there is no city water system; where the city water-supply is inadequate for fire protection in factories and other buildings, for water supply for small towns or villages; and in fact for almost any condition that may arise, requiring a system of water supply.

Fig. 94 illustrates a combination that will meet the requirements of the average small installation. The principal parts of this combination are a tank and a hand force-pump. The tank is supplied with a water gauge to show

the height of water. The action of the outfit is as follows:

After the connections are made as shown in the figure, the pump is operated to fill the tank. The water, entering the bottom of the tank, compresses the air in the upper portion, and gives the necessary pressure to deliver the water to the points desired through the pipe marked "supply to House." The gauge registers the pressure in the system. The amount of pumping to be done will depend, of course, on the quantity of water used, and for the average dwelling, a few minutes pumping every two or three days, will be sufficient to keep the system ready to respond to any demands made upon it for water.

If desired, power may be used, derived from a windmill, gas, gasoline, or hot-air engine, or

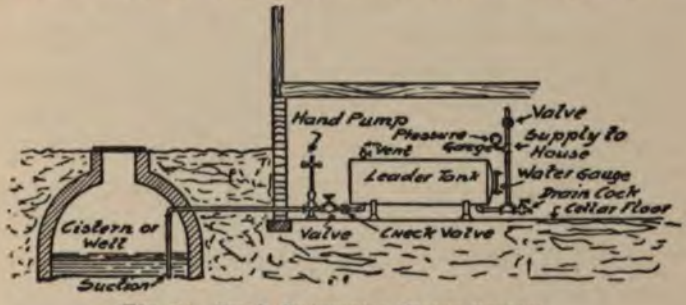


Fig. 94. Small Pneumatic Water System.
Pressure developed by hand force-pump.

electric motor, either in conjunction with the hand force-pump or not, as preferred. The "Leader" combinations may be fitted up to fill practically any and all requirements. A check-

valve should always be placed in the discharge pipe from the pump to the tank, to retain the pressure in the tank when the pump is not in operation.

Fig. 94 shows the tank placed in the basement of the building.

Fig. 95 shows a combination where the tank is buried in the yard, and the pump may be operated by hand, or attached to a windmill, as desired.

This form of water system is the favorite for country homes and farms. The use of the tank as shown does away with the old

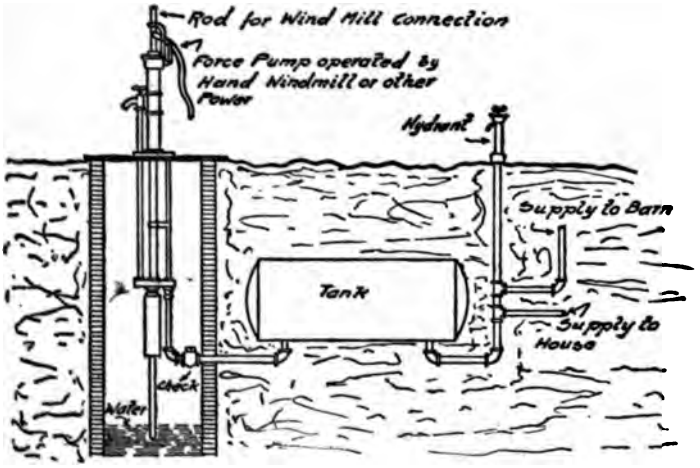


Fig. 95. Private Pneumatic Water System with Tank Underground and Pump Hand-Operated or Connected to Windmill.

method of placing the tank in the air on a platform, or in the attic of the house or upper portion of the barn, and gives a water pressure that would not ordinarily be obtained by the

latter methods; and it also eliminates the freezing feature that usually accompanies the latter.

With a pneumatic system, you practically have the same benefits that you would enjoy with the city water system.

Fig. 96 illustrates a **water-works system** which will fill the requirements for a small town or village of from 600 to 1,200 population, furnishing a water-supply for fire protection, domestic use, etc. This illustrates 3 tanks, 6 feet in diameter, 24 feet long, with a total capacity, in the three tanks, of 15,180 gallons; and the tanks may carry a working pressure of 100 pounds to the square inch. The pump has

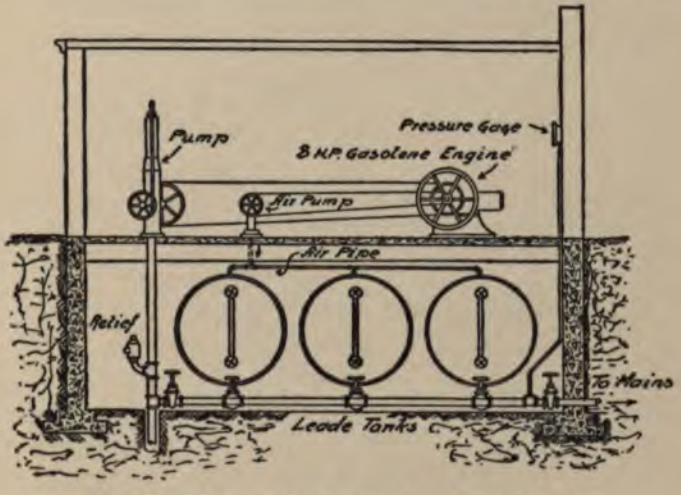


Fig. 96. Waterworks System for Small Town.

a daily capacity of 120,000 gallons, when pumping from a well where the water is not over 150 feet below the level of the pump. The pump is

operated by an 8-horse-power gasoline engine arranged to cut off automatically by the water-pressure. This feature reduces the cost of operating to a minimum. This system can be increased or diminished to suit local conditions, and furnishes a thoroughly up-to-date water-works system. The illustration shows the various parts of the system.

Fig. 97 is a side view of the system shown in Fig. 96, and illustrates the manner in which the tanks may be buried in the ground, which will afford protection against freezing and will also lesson the cost of installation. The tanks may be placed above-ground if desired; and

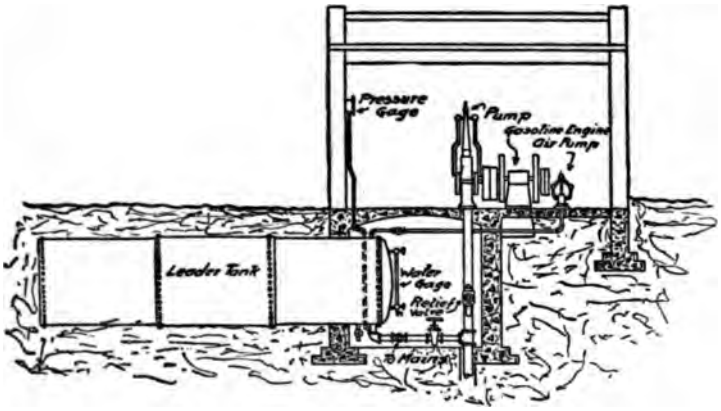


Fig. 97. Side View of Waterworks System for Small Town, as Shown in Fig. 96.

there is practically no limit to the combinations that can be made to suit local conditions or requirements. The following will give some useful information regarding the tanks:

Amount of Water in Tanks at Various Pressures

At	5 lbs.	pressure	the tank is	1/4	full of water.
"	10	"	"	2/5	" "
"	15	"	"	1/2	" "
"	20	"	"	3/5	" "
"	23	"	"	2/3	" "
"	30	"	"	7/10	" "
"	45	"	"	3/4	" "
"	60	"	"	4/5	" "

TABLE XVII

Data Regarding Tanks

Diameter	Length	Thickness		Weight	Gallons Capacity
		Shell	Head		
24 inches.....	6 feet	5/16 inches	1/4 inches	400 lbs	140
24 "	7 "	5/16 "	1/4 "	447 "	160
24 "	8 "	5/16 "	1/4 "	495 "	190
24 "	10 "	5/16 "	1/4 "	630 "	235
26 "	5 "	5/16 "	1/4 "	416 "	135
26 "	6 "	5/16 "	1/4 "	475 "	165
26 "	7 "	5/16 "	1/4 "	535 "	190
26 "	8 "	5/16 "	1/4 "	595 "	220
26 "	10 "	5/16 "	1/4 "	715 "	275
30 "	5 "	5/16 "	1/4 "	497 "	180
30 "	6 "	5/16 "	1/4 "	560 "	220
30 "	7 "	5/16 "	1/4 "	625 "	255
30 "	8 "	5/16 "	1/4 "	700 "	295
30 "	10 "	5/16 "	1/4 "	870 "	365
30 "	12 "	5/16 "	1/4 "	900 "	440
30 "	14 "	5/16 "	1/4 "	1,000 "	515
36 "	5 "	5/16 "	1/4 "	552 "	265
36 "	6 "	5/16 "	1/4 "	750 "	315
36 "	8 "	5/16 "	1/4 "	900 "	420
36 "	10 "	5/16 "	1/4 "	1,050 "	525
36 "	12 "	5/16 "	1/4 "	1,200 "	630
36 "	14 "	5/16 "	1/4 "	1,400 "	735
42 "	8 "	3/8 "	5/16 "	1,450 "	575
42 "	10 "	3/8 "	5/16 "	1,650 "	720
42 "	12 "	3/8 "	5/16 "	1,900 "	865
42 "	14 "	3/8 "	5/16 "	2,200 "	1,000
42 "	16 "	3/8 "	5/16 "	2,400 "	1,150
48 "	12 "	3/8 "	5/16 "	2,320 "	1,130
48 "	14 "	3/8 "	5/16 "	2,610 "	1,300
48 "	16 "	3/8 "	5/16 "	2,900 "	1,500
48 "	18 "	3/8 "	5/16 "	3,600 "	1,700
48 "	20 "	3/8 "	5/16 "	3,950 "	1,880
48 "	24 "	3/8 "	5/16 "	4,650 "	2,260

The above table gives a list of the common sizes; but tanks are built to other special sizes if desired.

It can be clearly seen, that the more water you force into the tank, the more the air in the

upper portion of the tank will be compressed, and the greater will be the pressure in the water system. This is a simple explanation of how the pressure is created to force the water through the piping to the desired points.

MARINE PLUMBING

This is a class of work that the average plumber does not meet with very often; and a little information may be of interest to those not acquainted with this class of work. The accompanying illustrations show what is known as the "Ellis" system of marine plumbing as applied to a modern yacht.

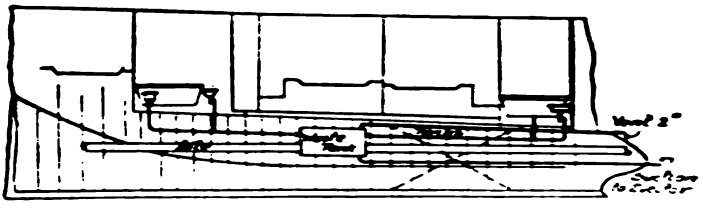


Fig. 98. Fore-and-Aft Section of Yacht with Ellis System of Marine Plumbing, Showing Roughing-In below Deck.

By the installation of this new system, it is possible to give the owner in his floating home all the conveniences which he may enjoy ashore, using exactly the same style of fixtures on board the vessel, even though they may be set several feet below the water-line, the same being thoroughly ventilated and complying in every respect with the sanitary laws demanded for buildings. Another great advantage is that the vessel is only pierced at one point for the dis-

charge of all fixtures. The discharge pipe is fitted with sea and check vales, thus providing a positive safeguard against back-pressure—a matter to be carefully considered by marine underwriters, as well as by the owner.

Figs. 98 and 99 illustrate a steam yacht fitted with this system, in which the roughing-in below the deck is seen. Owing to the fact that a fresh-water tank has been designed to take up the entire width of the vessel from the engine-room to a given point, which will interfere with the regular style of tank for waste, it is

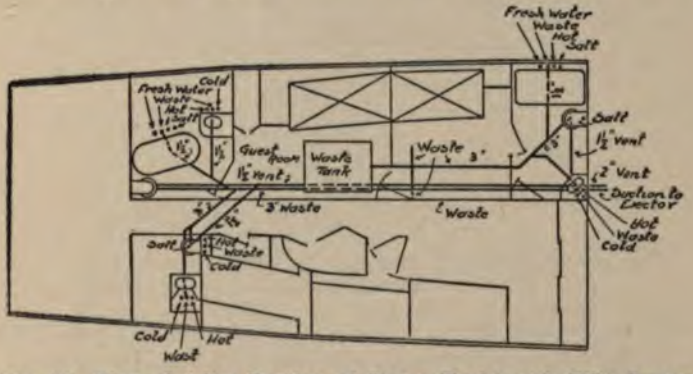


Fig. 99. Plan of After Portion of Steam Yacht with Ellis System of Marine Plumbing.

necessary to build a special drainage tank fitted to suit the space as shown. The drains and wastes from the owner's bathroom have to pass through the water storage tank by means of a sleeve with reinforced flanges at each end. The suction from the drainage tank also passes through in the same manner, to the automatic ejector placed in the engine room.

The water-closets used are of the **siphon jet type**, flushed with salt water from a small gravity tank placed on the upper deck.

The bathrooms have tile floors and wainscoting, and are provided with bath, basin, and closet. The baths are roll-rim, enameled, supplied with hot and cold fresh water and salt water, through improved faucets.

The basins are solid porcelain, supplied with hot and cold fresh water, with nicket-plated, exposed or "open-work" non-siphoning trap and waste. The drains and wastes are galvanized pipes, with recessed fittings and with lead

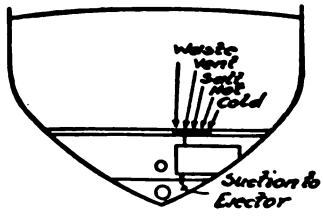


Fig. 100. Cross-Section of Yacht with Ellis System of Marine Plumbing.

bends to fixtures. The large supply lines are galvanized; and the small lines are brass, except where exposed, in which case they are nickel-plated.

Fig. 100 is a cross-section of the yacht to a point where the drainage tank is located, showing lines running from the engine room to the different fixtures.

The automatic ejector, Figs. 101 and 102, is placed in the engine-room, arranged to start at any desired point. It is operated by either com-

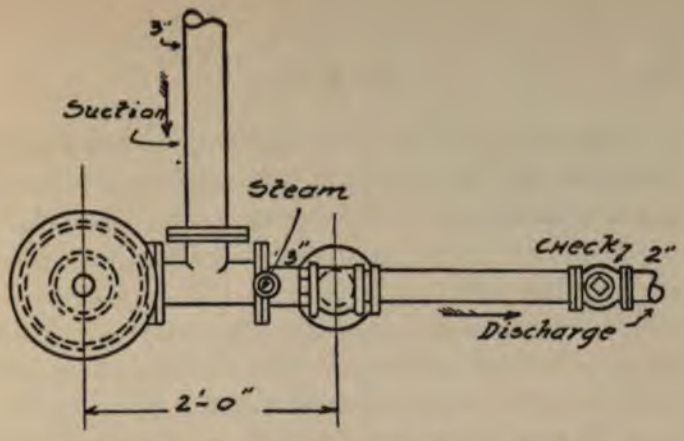


Fig. 101. Part Detail of Automatic Ejector for Marine Installation.

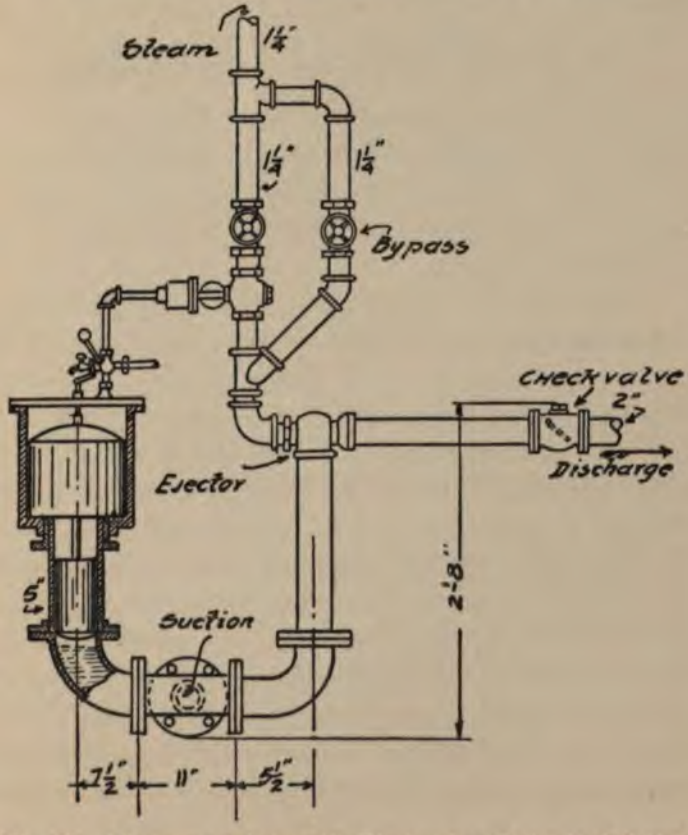


Fig. 102. Diagram of Automatic Ejector for Marine Installation.

pressed air or direct steam, and thoroughly empties the contents of the drainage tank at each discharge. The vents are connected together, and continued to a convenient point in the smokestack.

The dimensions of this yacht are 120 feet in length, 20 feet beam, and 180 tons displacement.

The above describes the average plumbing installation for marine plumbing; and a little study of the sketches will make the matter clear.

PRIVATE SEWERAGE SYSTEMS

It frequently happens that the plumber is called upon to install fixtures in localities where sewer systems, and the disposition of the waste matter from water-closets, become quite a problem.

Fig. 103 illustrates the use of the old-fashioned **cesspool.** For an ordinary residence, this may be about 10 feet deep, and 10 feet in diameter, and constructed of brick or stone laid up with without the use of cement or mortar, thus allowing the liquids to soak away through the ground, and the solid matter to remain at the bottom. If the cesspool has a closed top, this solid matter will be gradually reduced to a liquid state, by the action of a special kind of bacteria, or minute organisms, which live and thrive in dark, damp places. Care should be exercised in locating the cesspool, to avoid the contamination of surrounding sources of water

supply, such as wells, etc., and also to avoid the water getting into the basement of the building. It is good practice to locate the pool at least 50 feet away from the building.

A study of the sketch, Fig. 103, will make the manner of construction of a cesspool quite clear. If the ground is porous or absorbent, the size may be reduced to some extent; but when the pool is located in hard clay or other non-

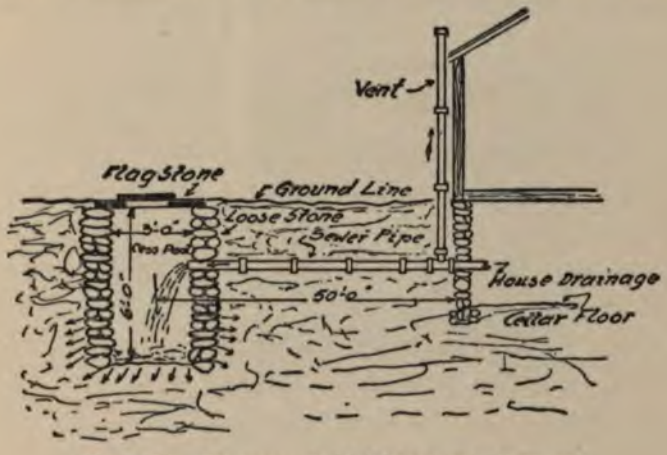


Fig. 103. Diagram of Old-Fashioned Cesspool.

absorbent earth, the above dimensions may have to be increased, depending, of course, upon the quantity of matter emptied into it—this can be easily determined.

Fig. 104 shows another type of cesspool, in which the sides and bottom are cemented to a point above the discharge pipe, thus retaining the solid matter until it is reduced to a liquid state. The grease, remaining at the top of the

pool, will not pass into the cobblestones placed around the outside of the pool to allow the water to pass from the outlet pipe quickly. The outlet pipe extends down below the line of the grease, thus passing clear liquid into the box drain placed above the cobblestones.

Cesspools are usually built circular in shape. The manhole cover on top will permit of access

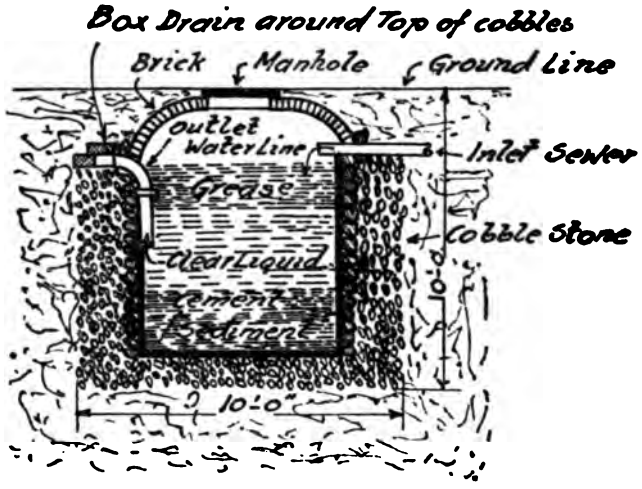


Fig. 104. Another Type of Cesspool

for cleaning when necessary—which is not often, as a rule, in porous soil, since numerous instances might be cited, of cesspools that have been in daily use for over twenty-five years without cleaning.

It is to be distinctly borne in mind, and strongly emphasized, that it is far preferable to dispose of sewage matter through a regular sewerage system than by any cesspool however

well constructed. As before said, however, there are times when the plumber is called upon to install plumbing fixtures where there is no regular sewer system, and he is then compelled to look for some other method of disposing of the sewage, and this calls the cesspool into the limelight.

Fig. 105 illustrates a **double cesspool,** where the outlet water is discharged into a stream, or over the surface of the ground, in gardens or

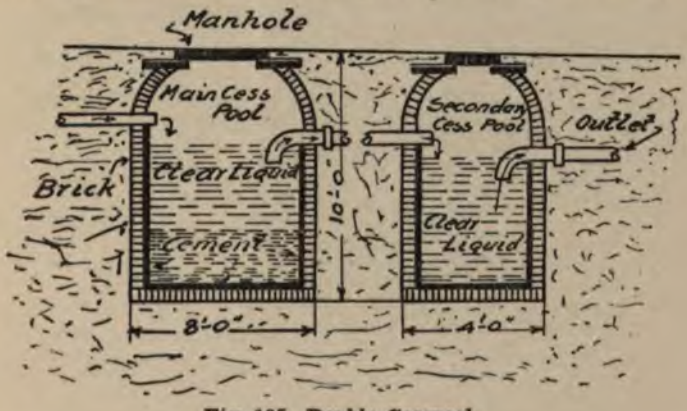


Fig. 105. Double Cesspool.

fields. This double arrangement insures the waste or outlet water being many times purer than it would be if it were passed through only one cesspool. Both the cesspools are cemented to a point above the water-line, retaining the water in themselves until discharged through the outlet pipe, and thus not saturating the surrounding earth.

There is nothing mysterious in the action of the cesspool, in the process by which the solid

matters are reduced to a liquid state by bacterial action, as other examples of this action may be seen daily, and perhaps never noticed. For instance, a quantity of waste water, containing some solid refuse, may be thrown upon the ground. The water will soak into the ground, or, in case it is thrown upon an impervious or non-absorbent surface, will stand

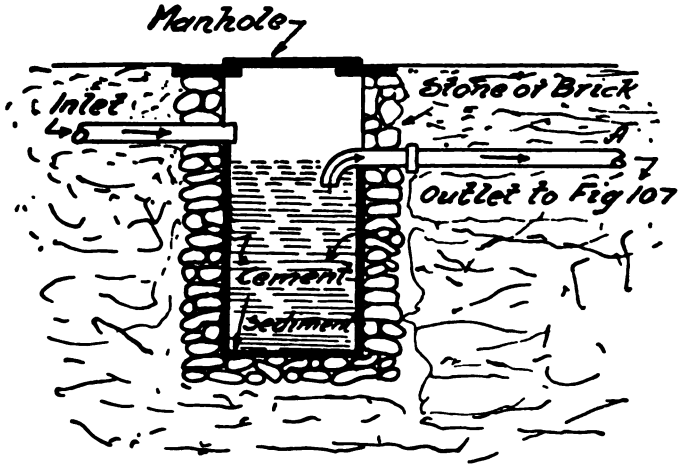
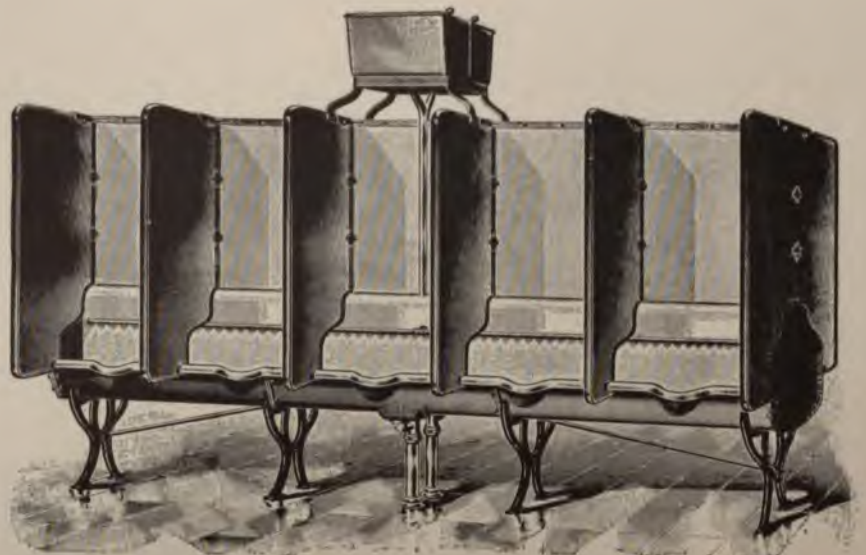


Fig. 106. Illustrating the Irrigating or Farming Process of Disposal of Sewage from Cesspool.

there until gradually taken up by evaporation. The bacteria immediately begin work upon the solid matter, but not so rapidly as would occur if the refuse were in a dark-moist place; and in time, the refuse is gone. This action is multiplied very rapidly in tanks or chambers built especially for this purpose, and many cities dispose of their entire sewage in this manner.

Fig. 106 shows a system of disposing of the



RANGE OF URINAL STALLS FOR FACTORY OR OFFICE BUILDING.

waste water from the cesspool, known as the **irrigating** or **farming process.** For an ordinary residence, the cesspool need not be so large as indicated in Fig. 104, as the waste water has more surface to discharge into. The outlet pipe is continued to a point in the garden or field, market **A,** where it is connected to the system of piping shown in Fig. 107, which is a plan

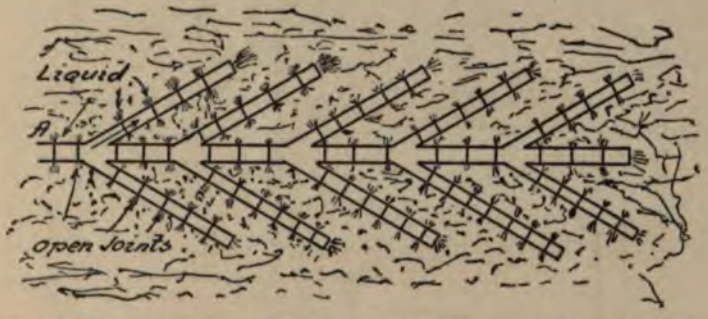


Fig. 107. Pipe System for Distributing Sewage in Irrigating or Farming Process.

view. This piping may be constructed of sewer pipe or field tile, with the joints open or uncemented, which will allow the waste water to escape rapidly into the surrounding earth. The lateral arms may be extended to as great a distance as may be desired to suit the requirements. This type of cesspool is perhaps the best of those described in this treatise, and may be used with some degree of satisfaction. There are a large number of this type in daily use and giving good results; but, as already insisted upon, if it is possible to discharge the sewage into a main sewer, do it.

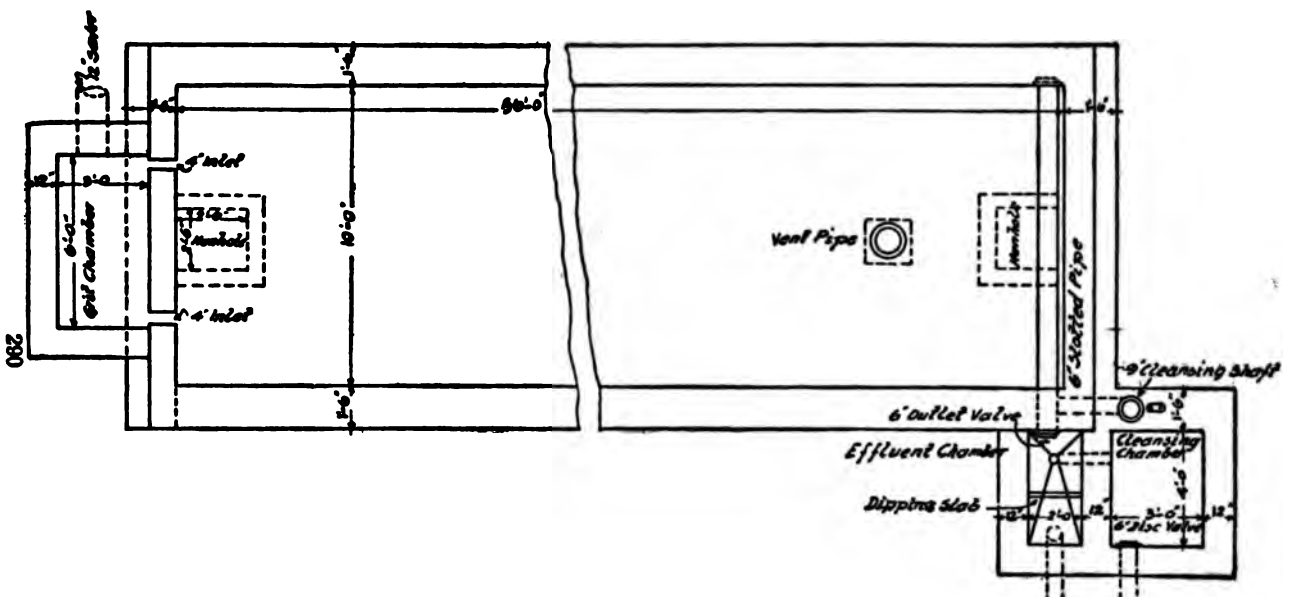


Fig. 108. Plan of Septic Tank for Disposal of City Sewage, Showing Relative Position of Grit, Effluent, and Cleansing Chambers.

A City Sewage-Disposal Plant

We shall now consider the construction and operation of a **sewage-disposal plant for municipal drainage.** This manner of disposing of the waste matter is giving universal satisfaction. The plant here described will take the entire waste of the town or city for which it is installed, breaking it up in the darkness of the **septic tank,** digesting it in the **contact-beds,** and pouring the effluent into a stream or other point, no longer the disgusting filth which entered the system, but water, clear as crystal and harmless as if distilled. Some of the contractors who install these systems even go so far as to drink the effluent, to show the thorough working of the plant.

The sewers will all empty into the main **septic tank,** which is shown in Fig. 108. The construction of this tank is such that the sewage moves through it with a scarcely perceptible current, the design being to keep the sewage in the tank about 24 hours in order to give the **bacteria** upon whose work the efficiency of the system depends a chance to break up and change to liquid form the solid matters contained in the sewage.

We are so accustomed to hear of bacteria as the enemy of mankind, that most of us forget—if indeed we ever knew—that there are many species of bacteria which are the friends of man. Acting as scavengers which live upon decom-

posing matter, they save man from the consequences of his reckless indifference to his own health and the health of others; and, when given the right kind of workshop, they very quickly dispose of all that is harmful and likely to breed disease germs.

While there are very many different kinds of bacteria, they are commonly divided into two classes, in accordance with the conditions under which they live and breed. These are the **anaerobic bacteria,** which flourish in the dark, shut away from all air and light; and the **aerobic bacteria,** which must have plenty of both light and air if they are to increase and multiply.

The Septic Tank. The workshop for the anaerobic bacteria is the closed tank above described. It is made as nearly air-tight as possible, only a small vent-pipe being provided for the escape of gas which is given off by the decomposition of sewage. The walls are built of concrete, and a concrete arch covers the tank completely.

The inlets to the tank are by way of a **grit chamber,** designed to catch road washings and other heavy substances which would clog the tank. The grit chamber has a cleansing valve to facilitate its being emptied whenever this becomes necessary. The two inlets dip well below the surface of the contents of the tank, in order that the force of the inflowing sewage may not break the blanket of thick scum which shuts

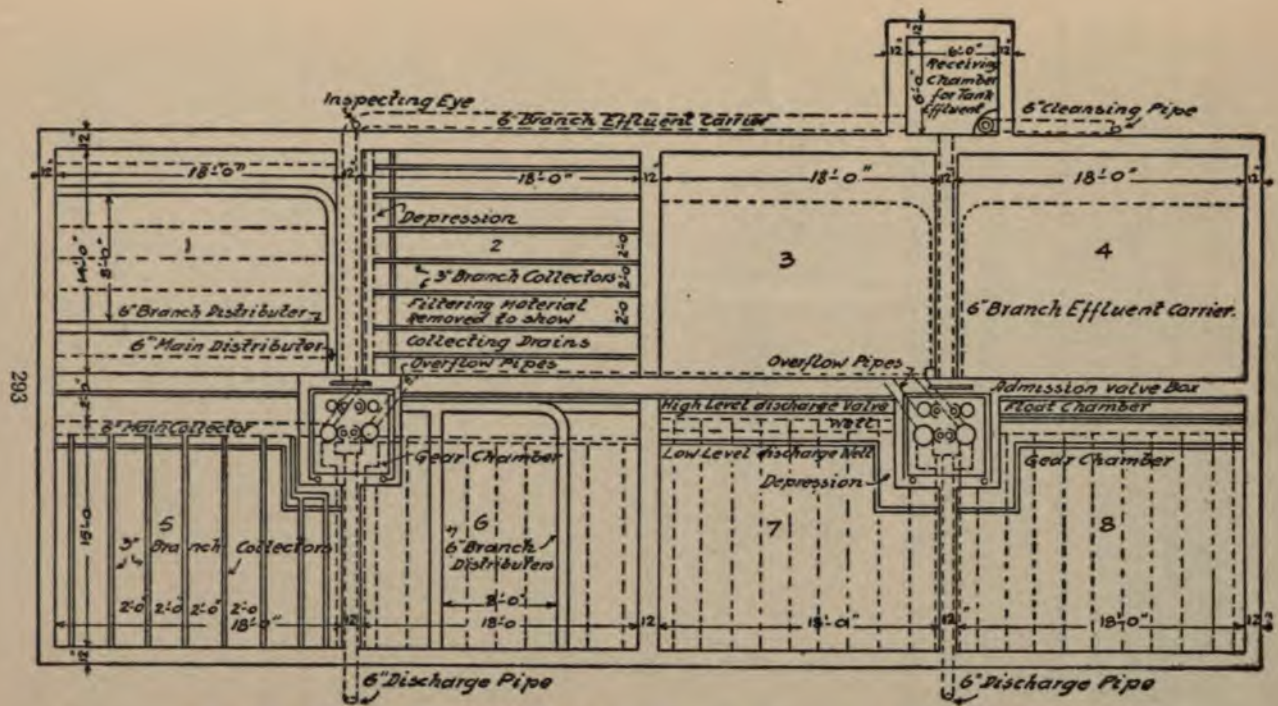


Fig. 109. Ground Plan of Contact-Beds, Showing Position of Gear Chambers and Distributing Drains.

[illegible] sewage flow [illegible] and air [illegible] [illegible] the manholes. [illegible] [illegible] [illegible]—millions in [illegible]—each [illegible] the incoming sewage, [illegible] [illegible] [illegible] in the form of some-[illegible]

[illegible] [illegible] [illegible] [illegible], and [illegible] [illegible] [illegible] a siphon pipe is set just [illegible] the surface of the contents, and through

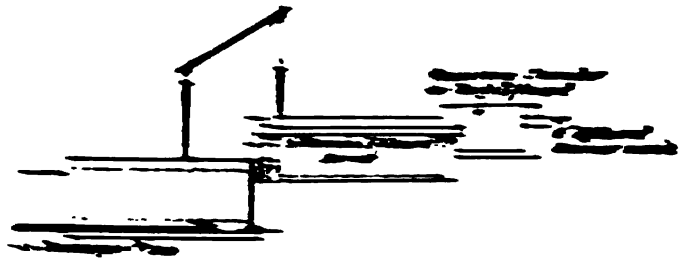


Fig. 11. [illegible]

[illegible] the escaping effluent finds its way to the **effluent chamber**, which a goose-neck draws it off into the effluent pipe, which carries it rapidly to the [illegible]

The **settling chamber** shown at the right in Fig. 9 is provided for the purpose of drawing off the sediment or mineral deposits which accumulate very slowly, being made up of such matters as the bacteria cannot break up. In sewage composed chiefly of domestic wastes, these substances are not very many in number, so that the sediment requires drawing off not more than twice a year at the most—which practically makes this part of the system a negligible factor.

The Contact-Beds. The contact-beds shown in Figs. 109 and 110, are the workshops of the aerobic bacteria, which take up the work where their busy neighbors left off, and carry it on to completion. Fig. 111 is a section through the effluent and cleansing chambers.

In order to supply the aerobic bacteria with the air and light necessary to their existence, these beds are filled with **clinker,** which pro-

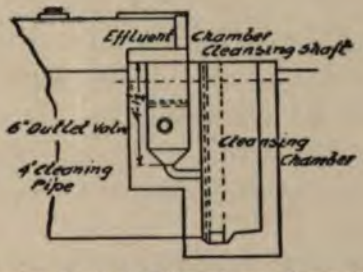


Fig. 111. Section through Effluent and Cleansing Chambers.

vides for the admission of the largest possible supply of air; and the operation of the beds is so arranged that each is given a rest of several hours before the period of work, thus insuring the aeration which keeps the beds from becoming clogged up with sewage through overworking the aerobic bacteria.

In the plant here illustrated, the contact-beds work in the cycle 1-3-2-4. Thus, while No. 4 is filling, No. 1 is empty, No. 3 discharging, and No. 2 full. Beds 5-6-7-8 are at a lower level than beds 1-2-3-4, and take the discharge from the beds above them, thus continuing the work of purification.

The apparatus for alternating the flow of sewage is automatic in its action, requiring only the attention of a man to oil it when necessary. A careful study of this text and the accompanying sketches will make the entire subject of the disposal of city sewage by means of a septic tank and contact-beds perfectly clear to the reader.

Why a Pump Works

The common **lift-pump,** shown in Fig. 112, has long been known, and has been used extensively since its construction. Its general appearance and method of operation are no doubt familiar to all readers of this treatise. But why does it work?

The hollow cylinder contains a valve at the bottom, which opens inward like a trap door. Into this cylinder a piston is fitted closely; and this piston is supplied with a valve, opening in the same direction as the one in the bottom of the cylinder. The pipe extending from the bottom of the cylinder down to and into the water below, is called the **suction pipe.** When the piston is lifted by means of the piston-rod, which is attached to the handle, the upper valve, known as the **outlet valve,** remains closed, being weighted down by the pressure of the atmosphere, which is usually figured as being equal to 15 pounds to the square inch. Lifting the piston creates a partial vacuum in the cylinder which causes the inlet valve to open and the

same pressure of the atmosphere causes air from the suction pipe to enter the cylinder. By reversing the handle, and pushing the piston down into the cylinder, the air, being compressed, closes the lower or **inlet valve,** and forces the upper valve open, which allows the air within the cylinder to escape through the hole in the

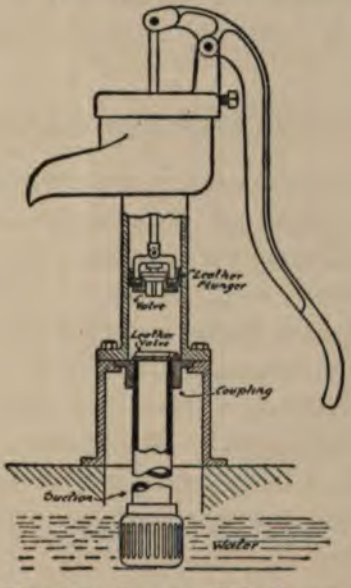


Fig. 112. Common Lift Pump.

piston. At the end of the stroke, the air which was contained in the cylinder has been pushed out through the piston and above it, and this air is lifted out of the pump by the next upward stroke. A few strokes will remove the remaining air from the suction pipe; and the pressure of the atmosphere upon the surface of the water below the pump causes the latter to follow the

air up the pipe and into the cylinder. The action of the water in passing through the pump is precisely the same as has been described with the air. All pumps, whether force or lift, whether vertical or horizontal, and whether for pumping liquids or fluids, operate upon the principle of removing the air contained in the cylinder and allowing the pressure of the atmosphere to replace it with the material which is being pumped.

HYDRAULIC RAMS

Hydraulic rams form a convenient and inexpensive method of delivering water from a lower to a higher point, and, after the first cost of installation, require very little expenditure for repairs, and require very little attention, as they work automatically.

A section of a so-called **double-acting** or **double-supply type** of hydraulic ram, is shown in Fig. 113. Considering it first without regard to the double-acting feature, suppose the opening at **H** to be closed. The valve at **B** being open, the water from the source of supply at more or less elevation above the machine flows down the drive-pipe **A**, and escapes through the opening at **B**, until the pressure due to the increasing velocity of the water is sufficient to close the valve **B**. At the moment when the flow through this valve ceases, the inertia of the moving column of water produces the so-called **ramming stroke**, which opens the valve at **C**, and com-

presses the air in the air-chamber **D** until the pressure of the air, plus the pressure due to the head of the water in the main, is sufficient to overcome the inertia of the moving column of water in the drive-pipe. This motion may be

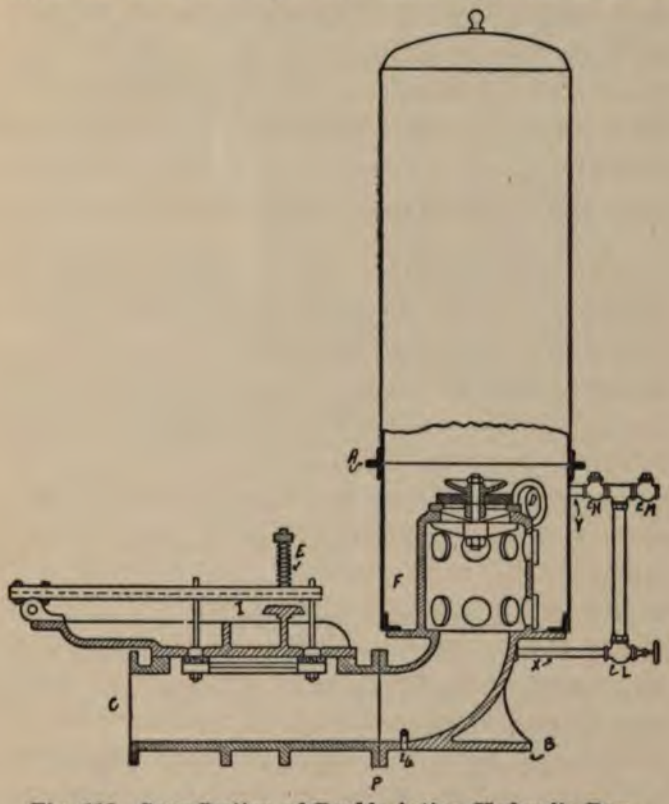


Fig. 113. Cross-Section of Double-Acting Hydraulic Ram. Capacity, 1,400 gallons per minute; weight, 6,000 pounds.

likened to the oscillations in a U-tube. At this instant the column of water in the drive-pipe has come to a rest; and the air-pressure being greater than the static head alone,

the direction of motion of the moving column is reversed, and the valve **C** closed. The water in the drive-pipe is then moving backward; and, with the closing of the valve **C**, a tendency to a vacuum is produced at the base of the drive-pipe: this negative pressure causes the valve **B** to open again, completing the cycle of operations. At the moment of negative pressure, the little snifting valve **E** admits a small quantity of air; and at the following stroke, this passes into the air-chamber, which would otherwise fill with water gradually, the air being slowly taken up by water. In many machines, the mistake is made of making the waste-valve **B** sufficiently heavy to overcome the static head of water in the drive-pipe. In fact, most writers on this subject state that the weight of the waste-valve **B** must be greater than the pressure of the static head of water on its under side, so that it may open when the column of water comes to rest.

In the machine above described and illustrated in the accompanying figures, this would be practically impossible, on account of the large area of the opening at **B**.

In this machine—known as the "Rife" hydraulic ram—the valve **B** is made as light as is consistent with the necessary strength, the negative pressure at the end of the stroke is relied upon to open the valve. With the largest sizes of these machines, this valve is 18 inches in diameter, and, with a head of 8 feet, which is a

common head for use with hydraulic rams, the static pressure on the under side of this valve is 883 pounds; it can very easily be seen that the great shock of a valve of this weight would rapidly destroy the valve and its seat.

The waste mechanism consists of a large port

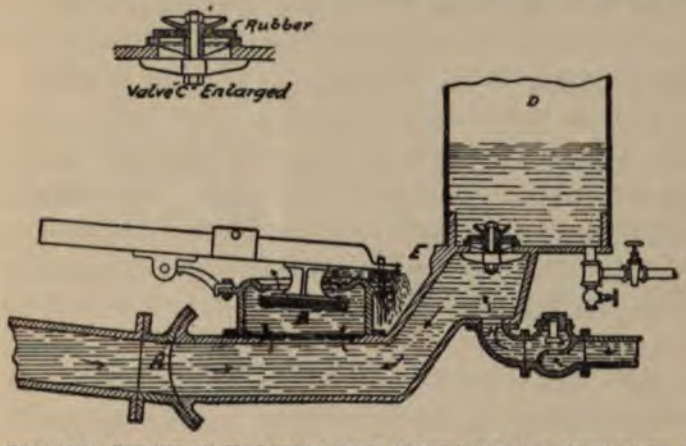


Fig. 114. Section of Hydraulic Ram, Showing Valve Mechanism in Air-Chamber.

with a flat, ample opening; and a large rubber valve with a balance counterweight and spring seating, removing almost entirely the jar at closing. The valve **C** in the air-chamber consists of a rubber disc with gridiron ports and convex seats, fastened at the center and lifting at the circumference, as shown in Fig. 114. The effort is to transfer the shock from the power of the driving water through the air-cushion, with the smallest amount of friction and jar.

After the closing of the valve **C**, the pressure of the air in the air-chamber forces the water in

the air-chamber out into the delivery pipes. It is claimed that water can be elevated as high as thirty feet for every foot of fall in the driving head.

To the reader who has carefully followed the above description, it will be clear that the most important detail in which the type of hydraulic ram here described differs from the ordinary hydraulic ram, is the **waste valve.** The counterweight on the projecting arm of this valve permits the adjustment of the valve to suit varying heads and lengths of drive-pipe. By adjusting the counterweight so that the valve is nearly balanced, the valve comes to its seat very quickly after the flow past it begins. The result is that the ram makes a great number of short, quick strokes which are much easier on the mechanism than slower and heavier strokes. Of course the stroke must be sufficiently powerful to act efficiently in overcoming the head in the delivery pipe. The adjustable weight permits this to be effected with the greatest nicety.

The question of efficiency of hydraulic rams has been much discussed, and such authorities as Rankine and D'Aubisson differ considerably in their calculations. The tables in this article are based on Rankine's formula in calculating efficiency, which is:

$$E=\frac{qh}{(Q-q)\ H},$$

in which Q is the quantity of water flowing per second in the drive-pipe; q, the quantity flowing

per second to the standpipe through the discharge pipe; **H,** the height from the escape valve to the level of the reservoir which feeds the drive-pipe; and **h,** the difference in the level of the water-supply reservoir and the water in the standpipe.

D'Aubisson states the formula for efficiency as:

$$E=\frac{q\ (H+h)}{Q\ H}.$$

D'Aubisson's formula is the correct one, considering the mechanism as a machine receiving energy at one end and delivering it at the other; while if the machine is considered as elevating water only from one reservoir to the other, Rankine's formula is the correct one to use.

The double-acting rams may be used to elevate pure water to a tank, using impure water for the driving water.

Directions for Making Surveys for Hydraulic Rams. In order to determine the proper-sized ram to be used for any installation, it is necessary to make a careful survey to obtain the following information:

(1) Flow of water per minute in gallons.
(2) Vertical fall in feet.
(3) Distance in which fall is obtained.
(4) Vertical height above ram water is to be elevated.
(5) Distance water is to be raised.
(6) How many gallons required per day.
(7) If a double-acting ram is required, flow in gal-

lons, of the spring water per minute; and the fall, in feet, from the spring to the ram.

(1) Determine this by the time necessary to fill a vessel of known capacity from the source of supply.

(2) Find the difference between the level of the surface of the water in the source of supply and the lowest point within a reasonable distance.

(3) State this difference.

(4) Find the difference between the level of the proposed location of the ram and the highest point to which the water is to be delivered.

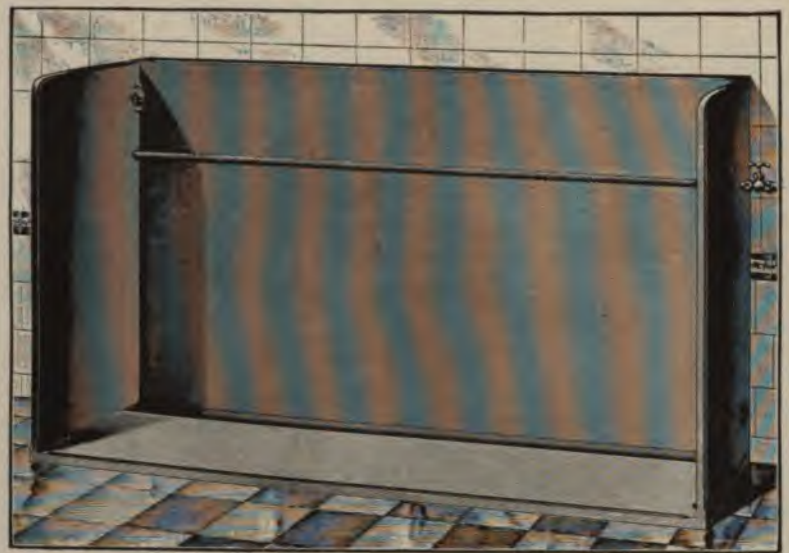
(5) Find the length of pipe necessary to conduct the water from the ram to point of delivery.

Length of Drive-Pipe. To insure sufficient air being fed automatically at each stroke, it is imperative that the drive-pipe should be of the proper length, which is determined by the fall to the ram, and the height to which water is delivered. In order to obtain the desired fall, it is frequently necessary to convey the water a greater distance than the length of the drive-pipe used.

Fig. 115 illustrates a method of securing the necessary head or fall.

(a) Locate the ram the proper distance from the spring or water supply, and connect as shown at **A.**

(b) Conduct the water to an intermediate



URINAL STALL WITH FLUSH PIPE.

reservoir (barrel, box, or standpipe) located the proper distance from the ram, connected as shown at **B.**

(c) Sink the ram in a pit to necessary depth and lay a drain pipe from pit to a lower point, as shown at **C.**

Double-Acting Rams—Directions for Setting. The ram should be on a level, firm foundation. It need not be fastened down. The drive-pipe must be set on a perfectly straight

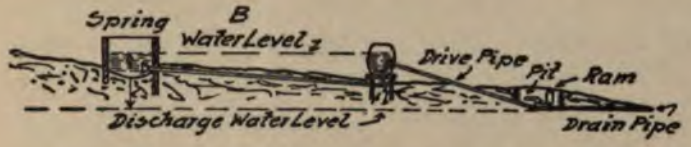


Fig. 115. Method of Securing Head for Hydraulic Ram.

incline, without bends or curves, except where the pipe enters the ram, and this should be done by bending the pipe. The upper end of the drive-pipe should be sufficiently below the surface of the water, so that it cannot suck air—say one foot or more. All drive-pipes should have a good open strainer on upper end. **Be sure that the drive-pipe is air-tight.** Use a quick-opening gate valve laid on side.

The delivery pipe can be laid with the necessary bends, according to the usual practice in water pipes. Connect all pipes before starting the ram, and leave them uncovered until it is shown that there are no leaks. Use gate valves on delivery pipe.

Start the ram by forcing the escape valve

open by hand; allow it to close, and repeat the operation until enough water has been forced into the delivery pipe to create a back-pressure, and cause the ram to work automatically.

At the start, put the slide weight over the center of the balance rod, and fasten securely. By raising and lowering the leather-covered rest under the balance valve lever, by means of the two nuts thereon, the opening of the valve can be lessened or increased, which will lessen or increase the amount of water used and delivered by the ram. The greater number of strokes, the **less** water is used and pumped. The fewer strokes, the **more** water used and pumped.

Under each condition, the ram runs best at a certain opening of this valve, and this can be determined only by experiment.

By changing the nuts on the lever rest, the position will be found where the ram runs with an easy, even stroke; then it is in proper working order.

The air-feed should be open at all times sufficiently to allow a small spray of water to escape at each stroke, thus insuring a constant supply of air, which prevents water-logging. The opening in the brass air-valve must "look down."

The **length** of drive-pipe is most important, and is governed by the ratio of the **fall** to the **elevation.** If too long or too short, the automatic supply of air is interfered with, and the efficiency impaired.

By using **batteries of rams,** unlimited amount

TABLE XVIII
Sizes of Hydraulic Rams

Number	Height	Length	Width	Size of Drive-Pipe	Size of Delivery Pipe	Gallons per Min. Required to Operate Ram	Least Feet of Fall	Weight
10	2ft. 1in.	3ft. 2 in.	1ft. 8 in.	1¼ in.	¾ in.	2½ to 6	3	150 lbs.
15	2 " 1 "	3 " 4 "	1 " 8 "	1½ "	¾ "	6 " 12	3	175 "
20	2 " 3 "	3 " 8 "	1 " 9 "	2 "	1 "	8 " 18	2	225 "
25	2 " 3 "	3 " 9 "	1 " 9 "	2½ "	1 "	11 " 24	2	250 "
30	2 " 7 "	3 " 10 "	1 " 10 "	3 "	1¼ "	15 " 35	2	275 "
40	3 " 3 "	4 " 4 "	2 " 0 "	4 "	2 "	30 " 75	2	600 "
80	7 " 4 "	8 " 4 "	2 " 8 "	8 "	4 "	150 " 350	2	1,500 "
120*	8 " 9 "	8 " 4 "	2 " 8 "	12 "	5 "	375 " 750	2	3,000 "
120†	8 " 9 "	8 " 4 "	2 " 8 "	12in.(2)	6 "	750 " 1,400	2	6,000 "

* Single.
† Duplex or double acting.

can be delivered. This is often done for fire protection purposes, and for supplying the water for small towns or villages, or large institutions.

The efficiency developed is governed by the ratio of fall to pumping head, and varies from sixty to ninety per cent.

In the hydraulic ram installation at the U. S. Naval Coaling Station at Bradford, R. I. (see

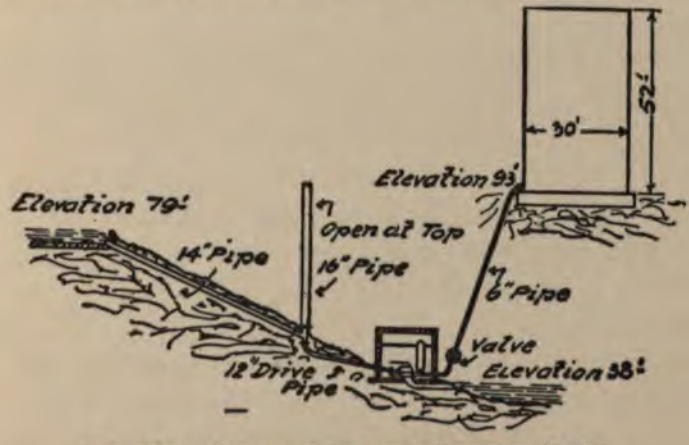


Fig. 116. Diagram of Hydraulic Ram Installation.

TABLE XIX.

Capacities of Hydraulic Rams

Power Head (In Feet)	Pumping Head (In Feet)																
	4	10	15	20	30	40	50	60	70	80	90	100	120	140	160	180	200
2	540	216	144	108	64	48	38	32									
3		324	216	162	108	72	57	48	41	36	32						
4		432	288	216	144	108	76	64	55	48	43	38	32				
5		540	360	270	180	135	108	80	69	60	54	48	40	34			
6			432	324	216	162	130	108	82	72	64	58	48	41	36	32	
7			505	378	252	189	151	126	108	84	75	68	56	48	42	37	
8				432	288	216	173	144	123	108	86	78	64	55	48	42	38
9				486	324	243	194	162	139	121	108	86	72	62	54	48	43
10				540	360	270	216	180	154	135	120	108	80	69	60	53	48
12					432	324	259	216	184	162	144	130	108	83	72	64	57
14					505	378	303	252	216	189	168	151	126	108	84	75	66
16						432	346	288	247	216	192	173	144	123	108	86	77
18						486	389	324	276	243	216	194	162	138	121	108	86
20						540	432	360	308	270	240	216	180	154	135	120	108
22							475	396	339	296	264	237	198	169	148	132	118
24							519	432	370	324	288	259	216	184	161	144	130
26								468	401	350	312	280	234	200	175	156	140
28								505	423	378	336	303	253	216	188	168	151
30								540	463	405	360	324	270	231	202	180	161

Example—With a supply of 1,400 gallons per minute, 10 feet fall, 50 feet elevation, a No. 120 Ram will deliver 302,400 gallons per day, 1,400×216=302,400. Multiply factor opposite "Power Head" and under "Pumping Head" by the number of gallons per minute **used** by the ram (see Table XVIII), and the result will be the number of gallons **delivered** per day.

Fig. 116), the efficiency guaranteed in the contract was seventy per cent, but the tests showed mean results in excess of this, as follows:

	No. 1	No. 2
Total water delivered to ram (gal. per min.)	582	578
Water delivered to standpipe (gal. per min.)	232	228
Power head in rams (feet)	36.75	37.25
Pumping head (in feet)	84.0	84.0
Strokes per minute	130	130
Efficiency (per cent, D'Aubisson formula)	91.23	89.06

These rams could have used 750 gallons per minute each; 582 gallons was all that was available when tests were made.

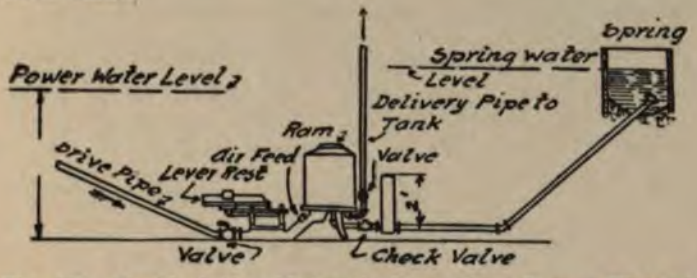


Fig. 117. Double-Acting Hydraulic Ram where Impure Water is Used to Pump Pure Water.

Fig. 117 illustrates the working of a double-acting ram, where impure water is used to pump pure water.

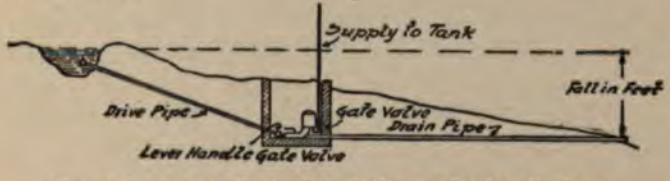


Fig. 118. One Method of Installing a Hydraulic Ram.

Figs. 118 and 119 illustrate methods of installing rams. A careful study of this article

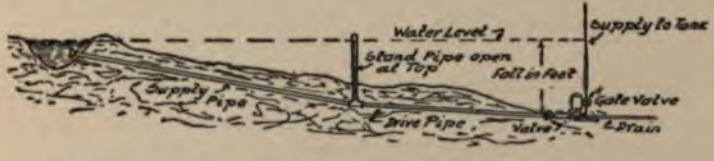


Fig. 119. Another Method of Installing a Hydraulic Ram.

will enable anyone to install these useful machines, and will open up a profitable field for the plumber in country work.

Hot-Water Tank Regulator

Fig. 10 illustrates the application of a typical automatic hot-water tank regulator to a tank for controlling the temperature of the water and holding it at practically any desired temperature. This form of regulator is adjustable in-

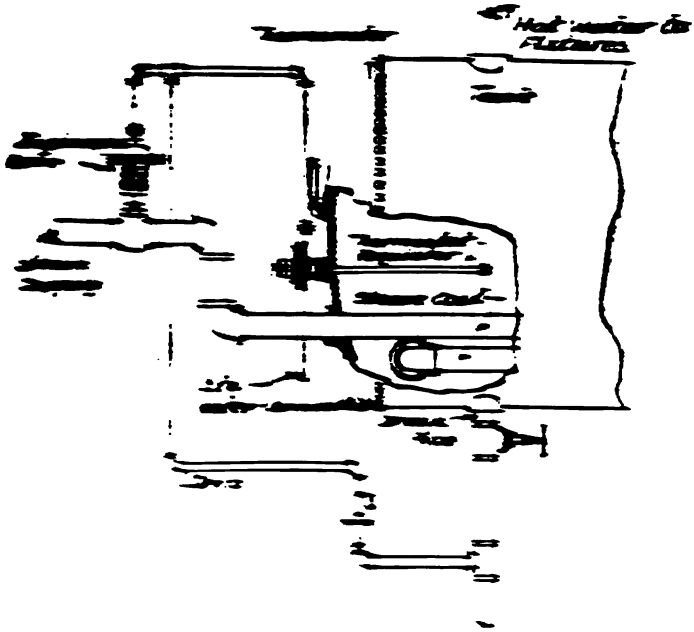


Fig. 10. Hot-Water Tank Regulator Installation.

stantly [illegible] temperature, by moving [illegible] which is located. The valve of the regulator is automatically operated by the expansion and contraction of a brass rod, which is part of the regulator inserted in the tank. There are no fluids or electric batteries used, the water pres-

sure doing the entire work of opening and closing the supply of steam to the steam coils inside the tank.

Automatic Instantaneous Water Heater

Fig. 121 illustrates a type of **water heater** which is designed to supply automatically a large

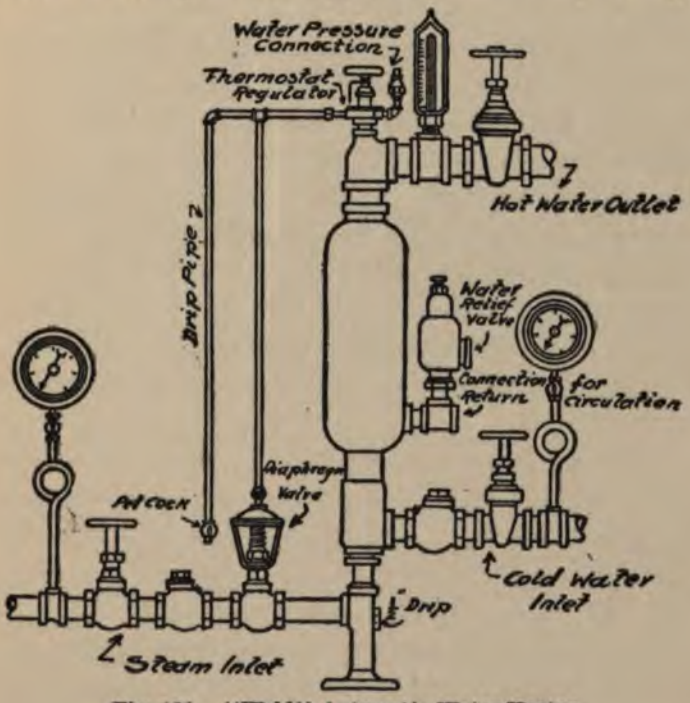


Fig. 121. "Weld" Automatic Water-Heater.

or small amount of hot water at any given temperature, for instant use. The water is heated as fast as it is drawn for use. The mixers in this apparatus are furnished in units, which allow large or small deliveries of hot water. This de-

vice makes it possible to dispense with storage tanks where exhaust steam is not available. These heaters are especially adapted for use in hotels, hospitals, manufacturing plants, laundries, and in connection with swimming pools and shower baths.

The Air-Lift

The **air-lift** is a simple arrangement of piping whereby water may be raised by means of **compressed air.** It depends for its action upon the difference in specific gravity between compressed air and water, and to some extent upon the expansive force of the compressed air. No valves are employed in the air-lift, except to regulate the admission of the air to the water pipes, and consequently there are no parts to become deranged and thus impair the operation of the pump.

The air-lift is employed for raising water and other liquids from comparatively small as well as great depths, it being found particularly economical in raising water from deep mines and bored or drilled wells. It is applicable to any place where water is to be raised, and has proven highly economical where compressed air has been used for other purposes previously to installing the air-lift, owing principally to the first cost of the apparatus.

The air-lift consists of two pipes—the **water pipe** and the **air pipe,** the latter being the smaller of the two. The water pipe contains a tapped

hole near the lower end, into which the air pipe is screwed, the latter, in some cases, being extended to about the middle of the water pipe, where it is bent at right angles so as to direct the air jet upwards. In other cases, the end of the air pipe projects slightly beyond the wall of the water pipe.

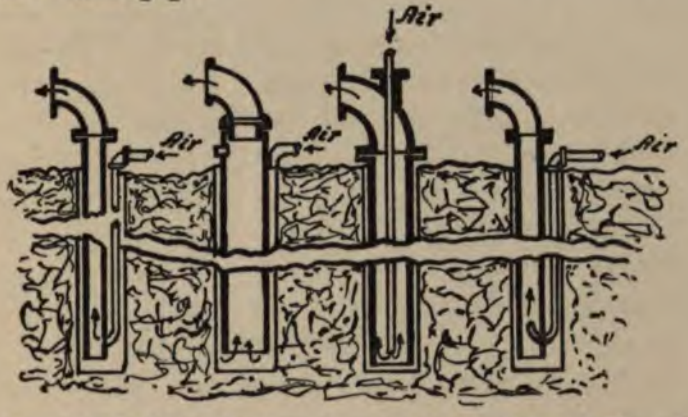


Fig. 122. Different Arrangements of Air and Water Pipes in Air-Lift.

There are several arrangements of air and water pipes, four of which are shown in Fig. 122. Air being forced into the water pipe, a huge bubble is formed about the orifice of the air pipe, as shown at **a** in Fig. 123, which fills the pipe and forms what may be called a piston of air. The pressure of the air when escaping from the air pipe is sufficient slightly to overcome the weight of the column of water in the water pipe, and a quantity of water equal to the volume of air admitted flows out at the top. The bubble of air immediately begins to rise through the water;

and, as it rises, it continues to expand, owing to the constantly decreasing weight of the column of water above it. The expansion of the air, and the consequent increase in volume, displace a corresponding volume of water at the top, until

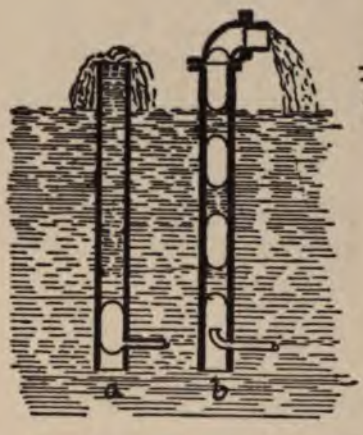


Fig. 123. Illustrating Action of Air-Lift.

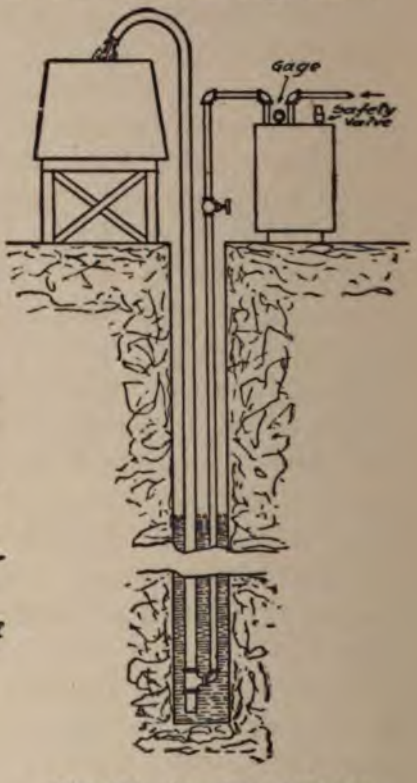


Fig. 124. Complete Air-Lift Installation.

the air reaches the outlet, where it escapes, carrying a quantity of water in the form of spray. The next bubble reaches the top in the same manner, and raises a similar quantity of water.

These air-bubbles form in rapid succession, thus dividing the column of water into alternate layers of air and water, each bubble or piston having a layer of water above it, as shown at **b** in Fig. 123 and also Fig. 124.

Fig. 124 shows the complete apparatus. It will be seen that after the column of water has once become divided into alternate layers of air and water, the air admitted at the bottom does not have a solid column of water to sustain or balance, consequently the pressure of the air may be reduced after the pump begins to work properly; and the volume of air thus reduced accordingly, lessens the work of the air-compressor.

The pressure of air required to operate the pump after it is once started, is considerably less than the pressure of the water due to the head; while the air-pressure required to start the pump is slightly greater than the water pressure corresponding to the head, and is generally equal to the water pressure per square inch, plus 5 lbs.

The successful operation of the air-lift depends principally upon two things—the ratio of depth of submersion to total lift, and the ratio of the area of the air-pipe to the area of the water pipe. The best efficiency, all things considered, is generally obtained when the ratio of depth of submersion to total lift is 0.65; and when the ratio of the area of the air pipe to that of the water pipe is about 0.16; in other words,

the submerged portion of the water pipe should represent sixty-five per cent of the total length, and the area of the air pipe should be sixteen per cent of the area of the water pipe. These ratios are not adhered to in all cases, and apparently without affecting the efficiency of the apparatus, which is probably due to differences in friction and air-pressure, temperature of water, and condition of water as regards purity.

When the depth of submersion is increased beyond about eighty-five per cent, the pressure must be raised; and the consumption of air, and consequently the volume of free air required per cubic foot of water raised, are increased. When the depth of submersion is considerably decreased—that is, below sixty-five per cent—the air-bubbles or pistons of air form irregularly and are of varying size, many working up through the water without causing a proper discharge of water, so that the volume of air required per cubic foot of water discharged is increased. The more economical range, therefore, when considering depths of submersion, lies between fifty-five and eighty per cent, and in the majority of cases it is not necessary to exceed these values. The depth of submersion referred to is the average depth measured from the water level before pumping, and when the water has lowered as far as it will go.

The ratio of the area of air to water pipe previously given (0.16), should be adhered to, regardless of the arrangement of the water and air

pipes, as shown in Fig. 122. The air pipe should be so proportioned that the velocity of the air will not exceed 4,000 feet per minute. When the air pipe is placed inside the water pipe, the area of the air pipe may first be determined, then the required size of the water pipe may be found by means of the formula,

$$\text{Diameter (in inches)} = \text{Cube root of } \frac{p6.24+P}{0.7854},$$

in which **p** and **P** equal the actual areas in square inches of the air and water pipes respectively.

The various levels may readily be indicated and measured, by means of a float and a stout cord. If the cord be run over a pulley $3^{13}/_{16}$ inches in diameter, and the float be lowered from the level of the ground, the depth to the water level in feet will be indicated by the number of revolutions made by the wheel while the float is descending. By counting the revolutions as the water level is lowered by the pump, the difference in levels may be similarly obtained. When the depth of submersion at starting is considerably lower than that previously referred to—eighty-five per cent of the total height of the pump—the air pipe should enter the water pipe from 30 to 35 inches from the bottom of the water pipe, to facilitate starting.

The volume of air required to raise 1 cubic foot of water by means of the air-lift, varies from 3.9 cubic feet as the minimum, to 4.5 cubic feet as the maximum, giving a mean of 4.2 cubic

feet of air per cubic foot of water. This is, however, a general statement, and applies only to air-lifts properly proportioned and working under favorable conditions.

The volume of air required per minute to raise a given volume of water in the same length of time, may be found by means of the formula:

$$\text{Cubic feet of air} = \frac{L\ C}{16.824},$$

in which **L** equals the lift in feet above the surface of water; **C**, the number of cubic feet of water to be raised per minute.

Transposing the symbols in the foregoing formula, we have for the capacity of the air-lift expressed in cubic feet per minute:

$$\text{Cubic feet of water} = \frac{16.824\ A}{L};$$

and for the lift corresponding to a given discharge and the approximate volume of air, we have:

$$\text{Lift in feet} = \frac{16.824\ A}{C},$$

in which **A** equals the number of cubic feet of free air per minute.

The efficiency of the air-lift, as previously stated, varies with the ratio of depth of submersion to total lift, the efficiency generally increasing with increased submersion up to approximately eighty-five per cent of the total lift, while the efficiency decreases slowly below

sixty-five per cent until the submersion reaches about fifty-five per cent of the total lift.

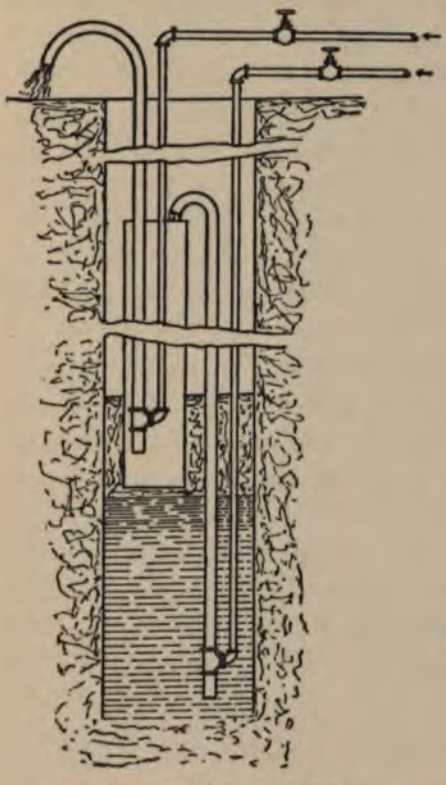


Fig. 125. Double Air-Lift Pump to Raise Water to Great Height.

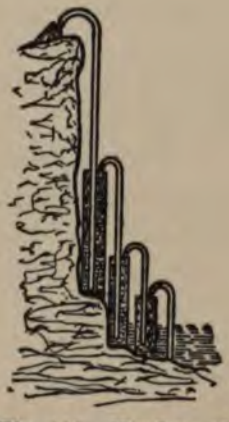


Fig. 126. Number of Short Lifts Connected.

The capacity in cubic feet per minute for varying depths of submersion beyond these limits may be found by means of the formula:

$$\text{Cubic feet} = \frac{8.24\ A\ D}{L2},$$

in which **D** equals the depth of the submersion in feet.

It is not practicable, under ordinary conditions, to attempt to raise water by means of the air-lift to heights exceeding 180 to 200 feet above the lowest water level; nor to attempt to carry the discharge pipe horizontally to a greater distance than 700 or 800 feet. When greater horizontal distances must be covered by the discharge, it is better to carry the pipe on an incline from the well or reservoir to the point of discharge.

When it becomes necessary to raise water to heights exceeding, say, 175 or 180 feet above the level of the well or reservoir, it will be found more economical, all things considered, to put in a second lift pump something on the plan of Fig. 125. And where the air-lift is to be employed in shallow reservoirs or shafts, a number of short lifts arranged in a manner similar to that shown in Fig. 126 may be employed. In the latter case, each lift should be correctly proportioned with reference to submersion and the lift above the water level.

INDEX

Heating and Ventilation

A

PAGE

Accelerated Systems..... 88
Accessories, Heating..... 114
Accumulating Tank..... 131
Air-Main 129
Air-Trap Radiation 135
Air-Valves 113
Air-Washer 145
Angle Valve..... 110
Apparatus, Modern Heating 4
Asbestos 158
Atmospheric Pressure..... 125
Automatic Damper-Regulator 116
Automatic Relief Valve... 132
Automatic Valves..... 114

B

Baldwin Rule..... 30
Base Elbow..... 80
Bends, Return 108
Blower 145
Boiler, Selection of..... 33
Boiler Insulation..... 157
Boiler Trimmings, Steam.. 114
Boiling Point of Water.... 141
Box Coil..... 107
Branch-Tee Miter Coil..... 108

C

Check-Valves 113
Chimney Flue..... 119
Circulator, Hydro-Vacuum.. 100
Circuit System 62, 82
Cleansing, Cold-Air..... 23
Coil
  Box 107
  Branch-Tee Miter..... 108
  Corner 109
  Flat 108
  Wall 108
Cold-Air Cleansing..... 23
Cold-Air Duct 106
Cold-Air Supply..... 21
Conduction 158

PAGE

Connections
  Expansion Tank..... 68
  Hot-Water Radiator..... 73
  Steam Radiator..... 56
Convection 158
Cork 158
Corner Coil..... 109

D

Direct-Indirect Radiators... 103
Direct-Indirect Radiation.. 103
Direct Radiators..... 103
Distributing Fittings, "O. S."..... 77
Divided-Circuit System..29, 40
Double-Swing Joint 52
Drainage Valve..... 132
Duct
  Cold-Air 106
  Warm-Air 106

E

Eccentric Fittings..... 28
Elbow, Base..... 80
Expansion Line..... 68
Expansion Pipe..... 68
Expansion Tank 68
Expansion Tank Connections 68

F

False Water-Line 56
Fan 145
Felt, Hair..... 158
Fitting
  "O. S." Distributing.... 77
  "O. S." Circuit..... 84
  Phelps Ideal..... 84
Fittings, Eccentric..... 28
Flat Coil 108
Flue
  Chimney 119
  Oblong 120

PAGE

Flue—*Continued*
Round 120
Square 120
Flues
Location 13
Size of..... 13
Forced Circulation System. 60
Furnace, Size of..... 10
Furnace Ventilation..... 23

G

Gate Valve..... 110
Gauge 115
Steam 115
Gauge-Cocks 115
Generator, Honeywell..... 88
Globe Valve..... 110
Gravity System..... 60

H

Heat-Economizer,
Pierce 88, 94
Heat-Generator, Milwaukee 102
Heating Accessories..... 114
Heating Apparatus..... 4
Heating
Vacuum 125
Vapor 125
Heat-Pipes 19
Heat-Retainer, Phelps..... 88
High-Pressure System..... 61
Historical Sketch..... 1
Honeywell Generator..... 88
Hot-Air Heating..... 7
Hot-Water Heating..... 60
Accelerated Systems..... 88
Pressure Systems..... 86
Hot-Water Radiator Connections 73
Hot-Water Radiator Valves 113
Humidity 144
Relative 144
Hydro-Vacuum Circulator.. 100

I

Indirect Radiation..... 103
Indirect Radiators..... 105
Insulation, Pipe and Boiler 157

J

Joint, Double-Swing..... 52

L

Lever Safety-Valve.....
Line, Expansion.....
Location of Flues.....
Location of Registers.....
Low-Pressure System.....

M

Magnesia .....
Mains, Sizes for Hot-Water Work .....
Main Pipes, Sizes of.....
Mercury Seal .....
Mills' Rule.....
Milwaukee Heat-Generator.
Mineral Wool.....

O

Offsetting .....
One-Pipe Circuit System...
One-Pipe System.....
One-Pipe System with Dry Returns .....
One-Pipe System with Wet Returns .....
"O. S." Circuit Fitting...
"O. S." Distributing Fitting .....
Overhead System.....
Overhead System of Steam Heating .....

P

Paper, Pressed.....
Phelps Heat-Retainer.....
Phelps Ideal Fitting.....
Pierce Heat-Economizer.88,
Pipe
Expansion .....
Safety .....
Pipe Insulation .....
Pipes
Heat .....
Sizes of Main.....
Sizes of Return .....
Piping for Accelerated System .....
Piping System, Valves on..
Pop Safety-Valve .....
Positive Valves.....
Pressed Paper.....

PAGE

Pressure, Atmospheric..... 125
Pressure Systems of Hot-Water Heating..... 86

Q

Quintuple Valve..... 138

R

Radiating Surfaces..... 103
Radiation
  Direct 103
  Direct-Indirect 103
  Indirect 103
  Methods of Determining. 30
Radiator Air-Trap..... 135
Radiator Connections..... 56
  For Hot Water..... 73
Radiator Valves..... 112
Radiators
  Direct 103
  Direct-Indirect 103
  Indirect 105
  Wall 58
Registers
  Location 13
  Size of..... 13
Regulator, Damper, Automatic 116
Relief Valve, Automatic... 132
Retainer Valve..... 131
Return Bends..... 108
Return Pipes, Sizes of..... 49
Rule
  Baldwin 30
  Mills 31

S

Safety Pipe..... 18
Safety-Valve 118
  Lever 118
  Pop 118
  Spring 118
  Weighted 118
Seal, Mercury..... 129
Sawdust 158
Single-Main System 82
Sizes of Flues..... 13
Size of Furnace..... 10
Sizes of Registers..... 13
Sizes of Main Pipes..... 49

PAGE

Sizes of Mains for Hot-Water Work..... 85
Sizes of Return Pipes..... 49
Spring Safety-Valve..... 118
Stack 106
Steam Boiler Trimmings... 114
Steam Gauge 115
Steam Heating 26
  Overhead System..... 51
  Two-Pipe System 55
Steam Radiator Connections. 56
Steam Radiator Valves..... 113
Surfaces, Radiating..... 103
Systems, Heating
  Accelerated 88
  Circuit ... .62, 82
  Divided-Circuit.....29, 40
  Forced Circulation 60
  Gravity 60
  High-Pressure 61
  Low-Pressure 61
  One-Pipe 29
  One-Pipe Circuit..... 35
  One-Pipe, with Dry Returns 42
  One-Pipe, with Wet Returns 47
  Overhead 51, 77
  Pressure, for Hot-Water Heating 86
  Two-Pipe 27, 64
  Two-Pipe Steam Heating. 55
  Single-Main 82
  Vacuum 125, 134

T

Tank
  Accumulating 131
  Expansion 68
Temperature Regulator.... 150
Thermometer 119
Thermostat 150
Trimmings, Steam Boiler... 114
Try-Cocks 115
Two-Pipe System.....27, 64

V

Vacuo-Vapor Method..... 134
Vacuum Heating System.125, 127
Valve
  Angle 110
  Automatic Relief..... 132
  Drainage 132

	PAGE
Valve—*Continued*	
Gate	110
Globe	110
Quintuple	138
Valves	110
Automatic	114, 132
Check	113
Hot-Water Radiator	113
Pipe	110
Positive	114
Radiator	112
Retainer	131
Steam Radiator	113
Vapor Heating	125
Ventilation	142

	PA
Ventilation—*Continued*	
Furnace	
To Secure	1

W

Wall Coil	1
Wall Radiators	
Warm-Air Duct	1
Water, Boiling Point of	1
Water Column	1
Water-Hammer	
Water-Line, False	
Weighted Safety-Valve	1
Wool, Mineral	1

INDEX

Plumbing

A

PAGE

Aerobic Bacteria..... 292
Air-Compressor, Automatic Hydraulic 247
Air-Lift 312
Anaerobic Bacteria..... 292
Area of a Circle..... 238
Area of a Rectangle..... 238
Area of a triangle..... 238
Asphaltum 250
Automatic Heater..... 203
Automatic Hydraulic Air-Compressor 247
Automatic Instantaneous Water-Heater 311
Automatic Water-Heater.... 217

B

Bacteria 291
  Aerobic 292
  Anaerobic 292
Ball-Cock 196
Basin-Cock, Measuring..... 267
Blow-Off Tank..... 272
Bathtub 176
Boiler, Range.....176, 203
Boiler Tube..... 195
Brass, Cement for..... 236

C

Capacity of Sewer Pipe.... 225
Capacity of Storage Tank.. 229
Cast Iron, To Harden..... 237
Cement for Brass and Glass. 236
Cement for Iron and Marble 236
Cement for Porcelain..... 236
Cement Mortar..... 237
Cement to Resist White Heat 236
Center, To Find, between Fittings 228
Cesspool 284
  Double 287
Chambers, Septic Tank
  Cleansing 294
  Effluent 294
  Grit 292

PAGE

Circle
  Area of..... 238
  Circumference of..... 238
  Diameter of..... 238
Circumference of a Circle... 238
Cistern Overflows..... 163
City Sewage-Disposal Plant. 291
Clean-Out Plugs..... 273
Cleansing Chamber, Septic Tank 294
Clinker 295
Closets
  Seat-Operating 269
  Siphon-Jet 282
Cock
  Corporation 193
  Sediment 205
  Stop 193
  Waste 193
Coils
  Range 203
  Sizes of..... 208
Compression Faucets..... 269
Compression Tank.....196, 261
Contact-Beds 291, 295
Continuous Venting.....184, 254
Corporation Cock..... 193
Coupling, Reducing..... 184
Crown 185
Cutting Soil-Pipe..... 167
Cylindrical Tank, Gallons in a 238

D

Discharge of Sewer Pipe... 225
Double-Acting Hydraulic Ram 298
Double Cesspool..... 287
Double Supply Hydraulic Ram 298
Drain, Floor..... 174
Drainage, Municipal..... 291
Drainage Fittings..... 250
  Recessed 250
Drinking Fountain..... 261
Drip-Pipe 212

PAGE

Drive-Pipe 304
Drum Tap..... 186

E

Effluent Chamber..... 294
Ejectors, Sewage..... 240
Electric Water-Heater..... 214

F

Factory Plumbing..... 267
Farming Process..... 289
Faucets, Compression..... 269
Fittings
  Drainage 250
  Recessed Drainage..... 250
Floor-Drain 174, 269
Flush-Valves 263
Fountain, Drinking..... 261
Fresh-Air Inlet..... 166

G

Galvanized Iron, Painting.. 235
Gas-Heater 176, 205
Glass, Cement for..... 236
Grafting Wax..... 236
Greenhouses, Painting Pipes in 235
Grit Chamber..... 292

H

Heater
  Automatic 203, 217
  Electric 214
  Gas 176
  Instantaneous 203
  Tank 207
Heaters, Instantaneous Hot-Water 211
Hot-Water Tank Regulator. 310
Hot-Water Supply..... 203
House Trap..... 162
Hydraulic Air-Compressor, Automatic 247
Hydraulic Rams..... 298
  Double-Acting 298
  Double-Supply 298
  Making Surveys for..... 303

I

Inch, Miner's..... 227
Increaser 184

PAGE

Inlet, Fresh-Air..... 162
Inlet Valve..... 296
Inscribing on Metal..... 237
Instantaneous Heater..... 203
Instantaneous Hot-Water Heaters 211
Instantaneous Water-Heater, Automatic 311
Intercepting Trap..... 162
Iron, Cast, To Harden..... 237
Irrigating Process..... 289

J

Joint-Runner 169
Joints
  Rust 228
  Soil-Pipe 168

K

Kitchen Range..... 176
Kitchen Sink..... 174

L

Laundry Tubs..... 174
Lavatory 176
Lead, Sheet..... 227
Lift
  Sewer 240
  Water 195
Lift-Pump 296
Low Point..... 205

M

Main Trap..... 162
Marble
  Cement for Iron and..... 236
  Rust Spots on..... 235
Marine Plumbing..... 280
Measurements, Roughing-In. 171
Measuring Basin-Cock..... 267
Metal, To Inscribe..... 237
Miner's Inch..... 227
Mortar, Cement..... 237
Municipal Drainage..... 291

O

Office Buildings, Plumbing in 240
Outlet Valve..... 296
Overflows, Cistern..... 163

P

PAGE

Painting Galvanized Iron... 235
Peppermint Test..... 201
Pipe
  Capacity of Sewer..... 225
  Discharge of Sewer..... 225
  Rain-Water 163
  Screw-Jointed 250
  Sizes of Sewer..... 226
  Suction 296
Pipes
  Vent 180
  Waste 180
  Water-Service 192
Pipe Work, Vertical..... 176
Piping System, The..... 170
Plugs, Clean-Out..... 273
Plumbing 161
  Factory 267
  In Office Buildings..... 240
  Marine 280
  Testing 198
Pneumatic Water System... 274
Porcelain, Cement for..... 236
Private Sewerage Systems.. 282
Private Water Systems..... 274
Pump 261, 296

R

Rain-Water Pipes..... 163
Rams
  Double-Acting 305
  Hydraulic 298
Range, Kitchen..... 176
Range Boilers.....176, 203
  Sizes of Galvanized-Iron.. 227
Range Coils..... 203
Recessed Drainage Fittings. 250
Rectangle, Area of..... 238
Reducing Coupling..... 184
Refrigerator Wastes..... 197
Regulator, Hot-Water Tank. 310
Roof-Flashing 179
Roughing-In 167
Roughing-In Measurements. 171
Rules, Tables, etc..... 225
Rust Joints..... 228
Rust Spots on Marble..... 235

S

Sanitary Tee..... 185
Screw-Jointed Pipe..... 250
Seat-Operating Closets..... 269
PAGE
Sediment Cock..... 205
Septic Tank.....291, 292
Sewage-Disposal Plant..... 291
Sewage Ejectors..... 240
Sewer 161
Sewers, Sizes of..... 164
Sewers and Connections.... 161
Sewer Lift 240
Sewer Pipe
  Capacity of..... 225
  Discharge of..... 225
  Sizes of..... 226
Sewer Traps and Ventilation 162
Sewerage Systems, Private.. 284
Sheet Lead..... 227
Sink, Kitchen..... 174
Siphon-Jet Closets..... 282
Sizes of Sewer Pipe..... 226
Sizes of Sewers 164
Sizes of Soil-Pipe 232
Smoke Test..... 201
Soil-Pipe, Cutting..... 167
Soil-Pipe Joints..... 168
Soil-Pipe Sizes.....232
Stack, Wash-Tray..... 177
Stop-Cock 193
Storage Tank 261
Storage Tanks, Capacity of. 229
Suction Pipe..... 296
Swab 161

T

Tables, Rules, etc..... 225
Tank
  Blow-Off 272
  Compression 196, 261
  Septic 291, 292
  Storage 261
  Capacity of Storage..... 229
Tank Heater 207
Test
  Peppermint 201
  Smoke 201
  Water 198
Testing Plumbing 198
Tee, Sanitary..... 185
Toilet-Room 269
Trap
  Drum 186
  House 162
  Intercepting 162
  Main 162

PAGE

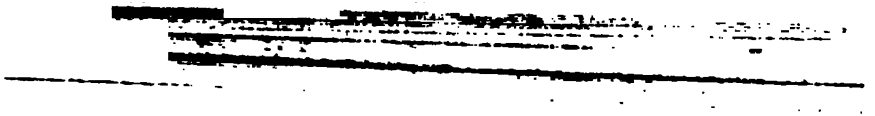
Trap—*Continued*
Sewer 162
Triangle, Area of..... 238
Tube, Boiler..... 195
Tubs, Laundry..... 174

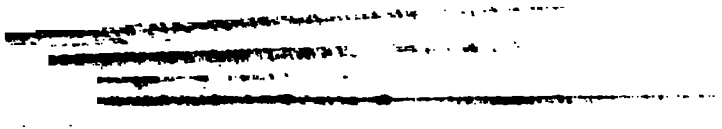
V

Valve
Inlet 296
Outlet 296
Waste 302
Venting, Continuous....184, 254
Vent-Pipes 180
Vertical Pipe Work..... 176

W

Waste-Cock 193
Waste-Pipes 180
Wash-Trays 174
Wastes, Refrigerator..... 197
Waste-Valve 302
Water-Backs 203
Water-Closets, see Closets
Water-Heater
Automatic 217
Automatic Instantaneous. 311
Electric 214
Water-Lift 195
Water-Service Pipes 192
Water Systems
Private 274
Pneumatic 274
Water Test 198
Waterworks System 224
Wax, Grafting..... 236





SEP 1 0 1953